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ELEMENTS

OF

CHEMISTRY.

BY

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THOMAS CHARLES HOPE, M.D. F.R.S.E.

&c. &c. &c.

PROFESSOR OF CHEMISTRY IN THE UNIVERSITY OF EDINBURGH.

My Dear Sir,

There is no one to whom I can dedicate these Volumes with so much propriety as to you, from whom I have derived whatever knowledge of Chemistry I possess; to whom also I feel indebted for many favours bestowed on me, both during the time that I acted as your assistant, and subsequently. Setting private considerations aside, on public grounds alone, I know none to whom a Work of this nature can be so properly inscribed, as to the most eminent Professor of the Science of which it treats.

Believe me,

My Dear Sir,

Your's sincerely,

ANDREW FYFE.

Edinburgh, *October* 1827.

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ERRATA CORRIGENDA.

Page 45. Line 12. *for* less *read* more.

Page 103. Line 15. *for* 6,000,000,000 *read* 95,000,000

Page 329. Line 6. *for* θεος *read* θεος.

Page 497. Line 7. *for* alkali *read* acid.

INTRODUCTION.

When we examine the objects of the universe as *unconnected* with each other, we study their shape and colour,—we inquire into the methods by which they have been formed, and endeavour to ascertain whence they are procured. When, on the contrary, our attention is drawn to the various *changes* that are daily going on among them, we view them *in connexion*,—we endeavour to find out their composition, investigate the laws by which they are influenced, and examine the results of the operations of these laws. Thus the study of the material world is divided into two great branches, Natural History, and Natural Philosophy; the former giving a description of the objects of the universe, the latter considering the laws by which they are governed.

The laws which influence matter, are those of Attraction and Repulsion. If a stone, held in the air, be let go, it instantly falls; or if a piece of sugar be put into water, they do not continue inactive, the former quickly disappears, and the latter acquires a sweet taste; changes ascribed, in both cases, to an *attraction* existing among objects, which, when they are under favourable circumstances, causes them to approach or combine.

On the other hand, when heat is applied to a body, it is enlarged; or if two loadstones be placed in a particular position, they instantly retire from each other;—an

effect opposite to the former, for, instead of being attracted, they are repelled; and which is ascribed to a *repulsion* existing among substances, or their particles, by which they are made to recede.

By the operation, then, of attraction and repulsion on the different objects of nature, are produced the various events which are daily going on around us. The heavenly bodies are retained in their places, and regulated in their movements; substances are presented to us, in the form of solids, fluids, and airs; and, by their operation, many important changes ensue on the approach of these to each other. To investigate these laws, to point out the changes produced by them, and to ascertain the powers by which they are influenced, constitutes that branch of science called NATURAL PHILOSOPHY.

But attraction and repulsion are of two kinds, distinguished by the objects on which they operate, and the changes they occasion. One kind acts on bodies placed at a distance, causing them to *approach;* a change of situation being the only one effected; while another acts on them only when in contact, causing them to *unite*, and undergo an alteration of properties.

These laws are still farther distinguished. The attraction which produces only change of situation, acts on *the mass;* the other, that occasioning change of properties, acts on *the particles*, making those of the one combine with those of the other, and form the new substance.

This difference between the different kinds of attraction,—the one acting on the mass, and causing only change of situation,—the other operating on the particles, and producing an alteration of properties, has given rise to the division of Natural Philosophy into two branches: the one, or the investigation of the former species, is called MECHANICAL Philosophy; the other,

or the examination of the latter, is termed CHEMICAL Philosophy, or simply CHEMISTRY.

These laws, however, are much influenced by other powers, as heat, light, electricity, and galvanism. In some cases they promote, in others they retard, their operation. They must therefore also be examined; the laws by which they are governed, and the changes they produce, must be illustrated. A wide field of investigation is thus presented to us:—We have to point out the nature and composition of bodies; examine the changes they undergo by the operation of attraction and repulsion; we have also to ascertain the effects of heat, light, electricity, and galvanism, and illustrate the laws by which they are regulated.

As we have thus not only to point out the nature and composition of bodies, and the changes they undergo, but also to investigate the powers by which attraction is influenced, Chemistry has been usually divided into two great branches, the GENERAL and PARTICULAR doctrines,—the former, including the investigation of heat, light, electricity, galvanism, and the circumstances attending the operation of attraction *in general;* the latter, containing an account of the composition and qualities of different bodies,—a division to which I intend to adhere in the present work; so that, after considering attraction, and the powers by which it is influenced, we have next to describe the properties of different bodies, dividing them, as usual, into the three great classes,—the productions of the mineral, the vegetable, and the animal kingdoms. With respect to the classification of inorganic productions, I am aware that that which I have adopted is not without its defects, but this is equally applicable to all the others yet recommended. It possesses one great advantage, however, that of bringing together substances, the properties of which are similar, and in which I con-

ceive the electro-chemical arrangement is so deficient. What bodies, for instance, are more dissimilar in their habitudes of action, than oxigen and chlorine, yet being considered electro-negatives, they are, according to this arrangement, treated of together; while chlorine is separated from sulphur and others, to which it bears, in many respects, a strong resemblance, particularly in forming compounds, the qualities of which are alike.

In the arrangement I have adopted, inorganic bodies are divided into acidifying and alkalifying principles *, acidifiable and alkalifiable substances, acids, alkalies, and compound salts. Acidifiable bodies are divided into simple and compound, and the alkalifiable ones are arranged under three heads; *first*, those forming bases commonly called alkalies; *second*, those forming bases called earths; *third*, those forming bases long called calxes or oxids. I have not, however, adhered strictly to the arrangement mentioned. For instance, after describing the alkalies, I have thought proper to consider the salts they form by their union with acids, while those of each earth, and common metallic oxid, are treated of along with the metal of which they are composed,—a deviation adopted for the sake of those who are attending lectures on Chemistry, for whose use this work is chiefly intended. After the consideration of the productions of the vegetable and animal kingdom, a few pages are given on Analytic Chemistry; and an Appendix is added, in which is contained matter that could not with propriety be elsewhere introduced, such as tables of the strength of acids, solubility of salts, &c.

* The term *alkali* is here used in its most extended signification, a *salifiable base*.

PART I.

SECTION I.

HEAT, OR CALORIC.

When a person places his hand on a piece of hot metal, a particular sensation is excited; or if he thrust the end of a poker into a fire, it soon becomes red hot. This is supposed to be owing to something passing from the metal to the hand, or from the fire to the poker, which, in general language, is called *Heat*. This term is, however, employed in a double acceptation,—to denote both the cause and the effect. A more correct language is now adopted by chemists, though even to it they do not adhere strictly. The word *Caloric* (derived from the Latin *calor*, signifying *heat*,) is used to denote the cause, while the term Heat is still retained to express the sensation. By Heat, then, we are to understand the sensation produced by a warm body; by Caloric, the active cause of this sensation.

Caloric is the most active agent in nature. All objects contain it; but different bodies have different quantities; and on this depends their *Temperature*. It has a tendency to pass from one substance to another, though differently, according to circumstances. In some cases, it passes slowly from particle to particle; in others, it darts through the air with immense velocity, from one body to another. In either of these ways heat is commu-

nicated, till an equality of temperature is established, unless prevented by the operation of some foreign power.

Besides these, Caloric produces other effects; thus, by receiving it a body is enlarged, and, as it continues to receive it, the enlargement increases, till it becomes either fluid or vapour.

Cold is generally believed to be merely the loss of caloric; the particular sensation excited, by what is called cold, being occasioned, not by any particular agent, but solely by the abstraction of heat.

The most vague ideas have, from the earliest times, been advanced concerning the nature of caloric, but only two opinions have of late been entertained with respect to it. According to some, it is, like gravity, merely a property of matter, and depends on a certain condition of the body; according to others, it is a peculiar kind of matter, governed by its own laws, and exerting different actions on substances. The former has been called the *Mechanical*, the latter the *Chemical* or *Material* theory.

That caloric is merely a property of matter, seems to have been advanced by Lord Bacon; and he was induced to adopt this opinion from considering the different facts concerning its evolution, more particularly during friction and percussion. Many bodies when rubbed become warm, and some even take fire, of which we have a good instance in phosphorus, for if a chip of it be put between paper, and rubbed, it is almost instantly kindled. In this way forests have been burned by the branches rubbing on each other during storms; machinery also, by the friction of the wheels, and ships, from the cables rubbing against their sides during the lowering of the anchor, have likewise been set on fire.

These facts drew the attention of other philosophers to the subject, but more particularly that of Count Rumford, who has made many interesting experiments on the subject.—(Essays, Vol. II.) In some of these, he employed the apparatus used for boring cannons. The instrument, weighing 15lb., was surrounded by 18lb. of water, at 60, which, in the course of an hour, rose to 107, and in $2\frac{1}{2}$ hours began to boil, the cylinder revolving 32

times in a minute. Rumford calculated, that the caloric given out in this experiment was equal to that of nine wax candles of $\frac{3}{4}$ of an inch in thickness, burning with a clear flame. The machine, during the boring, did not appear to be in the least exhausted of its power of generating it. The quality of the metals and of the water was not altered, and the air had no share whatever in the action; he therefore concluded that the source of the heat was merely *motion*, by which a vibration of the particles was excited, the intensity of the heat depending on the quickness and violence of the vibrations.

Sir H. Davy, who had espoused this side of the question, also performed some very interesting experiments regarding it.—(Beddoes' Med. Contributions.) By rubbing two pieces of ice together, he found that part of them was converted into water. Here then a change had taken place, and one, for the production of which a very large quantity of caloric must have been evolved; for, as will be afterwards proved, (*see Fluidity*), during liquefaction, heat is absorbed by the fluid that is formed.

Though these may appear strong arguments in favour of the immateriality of caloric, yet it is now almost universally admitted, that it is a material agent, possessing properties, and governed by laws, peculiar to itself; and when we consider the late important discoveries with respect to its existence in the solar ray, and the possibility of separating it from the light, we may view the question, with respect to its nature, as decided. Whether heat and light are distinct kinds of matter, or are merely modifications of each other, has not yet been determined. There are strong arguments in favour of both opinions. These, however, will be afterwards stated, when the properties of both have been detailed, and when the reader will be better able to trace the connexion between them. Considering heat as a material agent, we shall find that the different circumstances concerning its distribution, its communication, and the sources from which it is derived, are better explained, and more easily understood, than if we were to view it as a mere property of matter.

In treating of Caloric, it is intended to consider it under the following heads:

1*st*, Its *effects.*

2*d*, Its *communication.*

3*d*, The *quantity* of it in bodies.

4*th*, Its *sources*, under which are included the *sources of cold.*

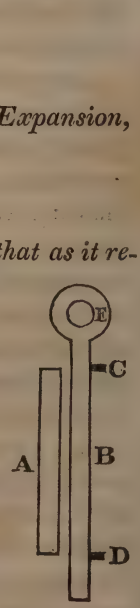
Though the subject of caloric is thus to be divided into these different heads, it is not intended to treat of them in the order mentioned. We ought to consider, first its communication, and the quantity of it in bodies; but before treating of these, it is necessary to explain the construction of thermometers, and the principles on which they operate, for without a knowledge of them, all that is said of the laws and effects of caloric would be unintelligible. Before considering its distribution, therefore, we have to treat of Expansion, and explain the use of thermometers, and how it is that by them we are enabled to judge of the effects of heat.

The Effects of Caloric.

The general effects of caloric are four,—*Expansion*, *Liquefaction*, *Evaporation*, and *Incandescence.*

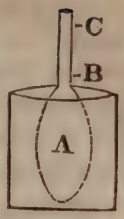
Expansion.

By the expansion of a body by heat is meant, that as it receives it, it is enlarged in all its dimensions of length, breadth, and thickness. That a solid is expanded by heat is shewn, by taking a rod of iron, A, for which we have a gauge, B, accurately fitted, so that it enters between the projecting parts C and D, and passes through the hole E at the end, when at a natural temperature. By putting it into a fire, and bringing it to a red heat, it will be so enlarged, as not to pass through the hole, or to go between the projections.



The expansion of a fluid is proved, by putting water, or spirit of wine, into a flask, A, and marking its height at B. If the vessel be put into a jug of warm water, as

the heat flows from the one into the other, the spirit is enlarged, as will be shewn by its rising in the neck of the vessel to C.



That air is expanded by heat is easily proved, by holding a bladder half full of it near a fire; the air in it is enlarged, so as to make the bladder quite tense.

Though bodies are thus expanded by caloric, the expansion is not permanent. When we withdraw the additional quantity of heat which occasioned it, they regain their original volume. Thus, if the bar of iron, when hot, be thrown into a basin of cold water, it will enter the gauge as before. The fluid, when removed from the jug, will quickly sink, so as to resume its former height; and the bladder, when taken from the fire, very soon becomes flaccid. This is generally called *Contraction.* Substances are said, therefore, to expand by heat, and to contract by cold; by which last term, it must be kept in mind, is meant merely the abstraction of caloric.

Bodies are not equally enlarged by heat. In the case of the iron, though that added far exceeded what was given to the others, yet it is necessary to have an instrument to ascertain that it is enlarged. The expansion of the fluid and air is easily perceived. We in general find, that objects increase in size, in the inverse ratio of their density. Thus aeriform substances, which are least dense, are most expanded; next come fluids, which are next in density; and lastly, solids, the most dense, are enlarged the least.

The enlargement of bodies in the *same state,* does not bear a strict relation to any of their other properties. In general, the densest enlarge the least; but this is not always the case. Thus metals are much denser than glass, but they are more expanded by the same addition of caloric.

There appears to be some relation between the expansion and fusibility of solids, as it has been found in a number of cases, that they follow nearly the same order in different bodies. Thus, in the table given by Ellicot, (Ph. Tr. xlvii.) the enlargement follows very nearly the

order of fusibility, but even to this there are also exceptions.

The expansion varies likewise in liquids, and as it is greater than in solids, the difference is more perceptible. Thus water is more enlarged than quicksilver, and spirit of wine more than water.

Though solids and fluids differ in their expansibility, it is the reverse with airs. It has been proved satisfactorily, that all bodies in this state are equally enlarged by equal additions of caloric.

It might be expected, that the enlargement would proceed regularly with the increase of temperature, but this is by no means the case; it proceeds in a greater ratio, as has been satisfactorily proved by the experiments of Dulong and Petit, (Ann. of Phil. xiii. 164.) They have found that, in solids, as metals, the expansion is not in proportion to the addition of heat. Thus that of iron from 32 to 212 F. was 1-282th, while from 32 to 572 it was 1-227th; that of copper, during the first, was 1-134th, and during the last, 1-177th. The same they have found is the case with fluids. The nearer these are to their freezing point, the less is the expansion, as is remarkably the case with water. Of course, as they approach the boiling point, the enlargement becomes greater: hence it is most nearly equal at the middle between these. Quicksilver, therefore, which has a great range of temperature between that at which it freezes, and that at which it boils, is, at the heats to which it is usually subjected, more uniform in its expansion than any other fluid; and hence it is preferred for thermometers.

Mr Dalton, (Elements of Ch. Philos.), has endeavoured to show the ratio by which fluids enlarge by the addition of caloric. This, he says, is progressive, being as the squares of the temperature, commencing at the point of congelation, or greatest density. Thus, if a fluid expand two degrees by the acquisition of a certain quantity of caloric, with double the addition it will enlarge 4, and with treble 9 degrees.

The preceding remarks concerning the irregularity of the expansion of bodies, apply to solids and fluids only.

It has been proved, by numerous experiments, that in airs it keeps pace with the addition of heat. It has also been ascertained, that it is 1-480th part for each degree of the thermometer, commencing at 32 F. *See Air.*

With respect to the cause of expansion, those who suppose that caloric is not material, imagine that it depends on the force of the vibrations separating the particles, and thus making them occupy more space than before; while the supporters of the material theory assert, that it is caused by the particles entering between those of the body, and thus removing them to a greater distance from one another. Prevost, however, alleges, that the particles do not actually recede, but that they merely assume a new arrangement, so as to cause the enlargement.

Caloric, it is thus evident, tends to separate the particles of a substance; cohesion, on the contrary, keeps them together; so that these are opposite powers, and hence may be explained the diversity in the enlargement of bodies, in their different states. Thus solids are enlarged less than fluids, the cohesion between their particles being strongest; in elastic substances, in which it is entirely overcome, the expansion is greatest. It would from this appear, that the enlargement is inversely as the cohesion, so that, had we any measure of the one, it would perhaps afford also an indication of the other. This opinion seems strengthened by the fact, that as the temperature of a body is elevated, by which the cohesion is diminished, the expansion always becomes greater; and again, the expansion of aeriform fluids, in which the cohesion is overcome, is not only the same in all, but it is in the ratio of the addition of heat.

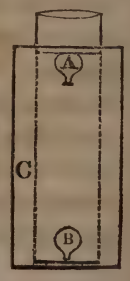
As bodies are expanded by heat, and as they all, even when at a natural temperature, contain it, it is evident that they must be in a state of expansion. That this is really the case may be easily shown, by putting any fluid, as spirit of wine, into a flask, marking its height, and placing it into a cold mixture, or one which will withdraw heat from it, as salt and ice, it will immediately begin to contract, and, of course, sink in the neck of the vessel. The same

would happen were we to cool a bar of iron, or a bladder filled with air. All bodies, therefore, are, even at a natural temperature, in a state of expansion.

As substances are enlarged by heat, and contracted by the loss of it, it is also evident, that their specific gravity must be changed. By specific gravity is meant, the comparative weights or quantities of matter in equal bulks of bodies. If, then, a substance be heated, by which it is expanded, it must contain less matter in the same space than before, it must therefore weigh less, consequently its specific gravity must be diminished. Suppose we have a small bottle, full of water, and having weighed it, we find that it contains exactly 1000 grains; by holding it in the hand for some time, so as to throw in heat, the fluid must be enlarged, part will therefore escape, so that it must weigh less than before, by that which is thrown out. The bottle still, however, continues full, that is, we have the same bulk of fluid, but of less weight, the specific gravity is therefore lessened.

As heat diminishes specific gravity, cold, or the abstraction of it, increases it; because, by occasioning a contraction, it brings the same matter into less space,—in other words, the same volume must contain more matter, and therefore must be heavier. Suppose, as before, that we have the small bottle full of water, and containing 1000 grains; if we apply cold, the fluid will contract, the bottle is therefore no longer full; so that, if we wish to have the same bulk, we must add more water, consequently it will weigh more. If, bulk for bulk, it is heavier, its specific gravity must be increased.

That a change of temperature alters specific gravity, may be shewn in another way. Put into a jar of water a glass ball, or any other object, so as just to float at A, and plunge this into a jug with a warm fluid, C; as the caloric enters from the one into the other, the ball will gradually fall to the bottom, B, shewing that the density of the water has been diminished. On the contrary, if a ball be put into water, so as just to sink to the bottom, B, and the vessel be surrounded by a cold mixture, C, as the fluid



loses its heat, the ball will rise to A, shewing that the density, or specific gravity, has become greater.

The change in specific gravity by an alteration of temperature, is also beautifully illustrated by the movements occasioned in the particles of fluids and airs, by the addition and abstraction of caloric. If heat be applied to the bottom of a jar of water, the particles below, as they receive it, are enlarged, and ascend, owing to their diminished specific gravity ; the colder ones fall, also gain caloric, are expanded and rise, so that there is a constant ascent of warm, and descent of cold particles. These movements are much more apparent if some flocculent substance be suspended in the fluid, and for this purpose we have merely to throw in a little of the solution of any earthy salt, as alum, and afterwards that of potashes, by which the earthy matter is separated in fine powder.

If, on the contrary, we apply cold to the surface of the fluid, the particles above, as they give out their heat, contract and sink, because their specific gravity has become greater ; the warmer particles rise to supply their place, they also lose caloric, contract and fall, so that there is thus a constant current of cold particles downwards.

The change in the specific gravity of aeriform fluids, may be illustrated in the same way. If a red hot poker be held in the air, and a person place his hands, the one above, the other below it, and at equal distances, that which is above is more warmed than the other, because the particles of air in contact with the poker, as they receive heat, are expanded, and rise, while others rush in to supply their place, and acquiring caloric, also expand and ascend, so that the heated air is constantly flowing to the hand above. On the contrary, if a piece of ice be held in the situation of the poker, the hand beneath is most cooled, because the particles of air giving forth their caloric to the ice, are diminished, become therefore of greater specific gravity, and fall.

Since specific gravity is thus so easily changed, it is necessary, when attempting to find that of any body, that we be particular in attending to temperature. For

this reason Chemists have usually fixed on 60 F. as a standard; but, in general, in stating the specific gravity, the temperature at which it was taken is also mentioned.

The force with which expansion occurs, is very great. If a bar of iron, fixed at both ends, be heated to redness, it expands with such force, that it either bends, or bursts asunder, the parts to which it is attached.

The general law of expansion is applied to many useful purposes; but it is also a source of great inconvenience. The cracking of glass vessels, and other bodies of a similar nature, is occasioned by it. When warm water is poured into a cold tumbler, the particles within, as they receive heat, expand, but owing to the slow transmission of it through the glass, those on the outside continue for some time as they were, they do not therefore yield to the inner ones, and a crack is the consequence. On the contrary, when cold water is put into a warm glass, the inner particles, as they lose their heat, contract, while the outer ones remain expanded, they do not follow the others, and hence also the vessel is cracked. This points out the necessity of warming or cooling glass gradually, to allow time for the uniform expansion or contraction. The cracking is also prevented by having the vessels very thin, by which, should they be suddenly heated or cooled, the whole is almost instantaneously expanded or contracted.

There is, perhaps, no artist put to so much inconvenience from expansion as a clock-maker. Clocks, which are made of metal, are much affected by a change in the volume occasioned by an alteration of temperature, which causes the movements to vary at different times; but the pendulums are more particularly affected. The quickness of the vibrations of a pendulum depends on its length,—the longer it is, the fewer the vibrations in a given time. If therefore it be lengthened by heat, they become fewer, and consequently the movements of the clock are slower. Luckily, however, a remedy for this defect has been discovered, and in the very source of the inconvenience itself. All the different kinds of Compensation Pendulums are on the same principle, but the simplest, and the one

most easily understood, is that called the Gridiron Pendulum, so termed from its appearance. It is composed of two metals, iron and brass, the latter of which expands twice as much as the former, by the same addition of heat. When properly constructed, it consists of two iron rods, A B, and four brass rods, C D, fixed in the cross bars, E F, G H. The upper end of A is the point of suspension, and, after passing through a hole in E F, its lower one is fixed to the bar G H. The lower extremity of B has the ball attached to it, while, after passing through a hole in G H, its upper one is fixed to E F. The brass rods are all rivetted to the cross bars. Suppose heat is applied to this pendulum, by which each iron rod expands half an inch, the ball would thus be thrown an inch down; but as the brass expands twice as much as the iron, each rod would be lengthened an inch, and throw it an inch up, the four rods acting merely as one. Since, then, the lengthening of the brass raises it just as much as that of the iron tends to depress it, the pendulum is kept always of the same length, and the movements of the clock are not liable to be affected by a change of temperature.

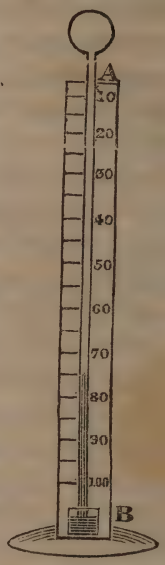


Though expansion is a source of great inconvenience, yet it is put to many useful purposes. A wheel-wright daily resorts to it, for fixing the hoop on the wooden part of the wheel. For this purpose, having made it a very little less in diameter than the other, he expands it by bringing it to a red heat, and, when in this state, he puts it on the wheel, and instantly dashes cold water on it, by which it contracts, and embraces the wheel tightly. It frequently happens, that the stopper of a bottle becomes fixed; it may however, in general, be taken out, by having recourse to expansion. The corner of a towel is dipped in warm water, and applied around the neck, so as to throw caloric into it, and cause it to expand, by which its diameter is enlarged, before the stopper receives

any heat, so that, by giving it a slight blow with a piece of wood, it is easily removed.

By far the most useful application of expansion is, making it a measurer of temperature. As the increase of volume is not great, different methods have been resorted to for indicating any slight change. The instrument, now brought to a great state of perfection, is called a THERMOMETER, from θερμη, *heat*, and μετρον, *measure*.

The first thermometer was that contrived by Sanctorio, an Italian physician, of the 17th century. It consists of a tube, A, with a ball blown at one end, which, with part of the tube, is filled with air; the remainder contains a red fluid, the open end being placed in a cup of it, B. Suppose that the fluid stands at 40, and heat be applied to the ball, the air within, as it receives caloric, will be expanded, and force it down. If, on the contrary, cold be applied, the air within, as it loses its heat, will be contracted, the fluid must therefore rise. As each addition, or abstraction, will always cause the same expansion or contraction, we have thus an indication of the change in temperature. This instrument, though extremely delicate, answers for certain kinds of experiments only; it has therefore undergone various alterations, perhaps the best of which is to make it of this form. It is merely the tube bent near the ball, by which we can keep this below, and thus plunge it into a substance, with a view of finding its temperature. In this modification, a part only of the ball is filled with air, the remainder, with part of the tube, contains the fluid. On applying heat to the ball, the air will expand, and cause the liquid to rise.





The different modifications of the Sanctorio, or air thermometer, though extremely delicate, are liable to one very great objection. It will be afterwards proved,

that the atmosphere, though a light substance, yet, from its great bulk, presses on this earth, and other objects, with a weight of 15 lb. on the square inch. As this varies at different times, it must exert unequal pressure on the liquid in the cup of the one, or in the tube of the other, and thus cause it to stand at different heights, though there has been no change in the temperature of the air within the ball, the alteration in volume being occasioned, not by an alteration of *temperature*, but of *pressure*. Professor Leslie has, however, obviated this objection, in his *Differential* Thermometer. It consists of a tube, forming three sides of a square, with a ball as nearly as possible of equal dimensions at each end. After the introduction of the red fluid, the tube is sealed by a blow-pipe, so that it is thus cut off from being affected by any change in the pressure of the atmosphere. On applying heat to a ball, the air in it enlarges, and forces the fluid down, making it of course rise in the opposite stem. Again, on applying cold, the air contracts, and the liquid regains its former height. This instrument has been called a differential, because it points out the difference between the temperature of the two balls; and that it does so is evident, for if it be brought from a cold to a warm room, provided the balls are alike in all respects, the heat will act equally on both, so that the air in both will continue as it was, and there will therefore be no change in the height of the fluid.



Though the thermometers now described are extremely delicate, they answer for certain experiments only. A very great improvement was introduced, by substituting for air, a fluid, the expansion of which should indicate the temperature. Those in general use are spirit of wine and mercury, the former for ascertaining low degrees of heat, as it cannot be made solid by any cold we can apply to it; the latter for high temperatures, as it requires considerable heat to make it boil. The thermometer now used, consists of a slender glass tube, with a bulb at

one end, which, with part of the tube, are filled with the fluid. Before using a tube for making a thermometer of it, it is necessary to ascertain if it is of equal dimensions throughout. This is done by immersing one end into mercury, placing the finger on the opposite end, and after removing it, holding it horizontally, and measuring the length of the fluid. By taking off the finger, and inclining the tube, it will flow on to another part, where it must be again measured, and, by repeating this several times, it will be ascertained if it is of equal calibre throughout; for, if so, the fluid will be at each part of the same length. If not uniform in its diameter, it must be rejected, because, if made into a thermometer, the temperature indicated by the expansion will not be correct. The introduction of the fluid, though at first sight it may appear difficult, is easily accomplished. By the application of heat to the ball, part of the air is expelled, so that, if the open end be then plunged into it, it will enter to supply its place, being forced in by the pressure of the air. By again applying heat, the fluid is made to boil, by which the whole of the air is driven out, and the ball and tube are filled with vapour, which, as its temperature falls, is condensed. A vacuum is thus procured, so that, if the mouth of the tube be instantly plunged into the fluid, it is forced in and fills it. After this, the open end is shut by a blow-pipe, expelling as much as possible, the atmospheric air still remaining in it, that it may not, as the liquid rises, impede its ascent. This is done by expanding the fluid till it reach near the end, and sealing the tube when in this state.

The principle on which the thermometer operates is by the general law already noticed, that an equality of temperature is soon established between different bodies. When, then, a thermometer is brought into contact with a substance warmer than itself, the fluid in it receives caloric, by which it is expanded, and rises in the stem. When, on the contrary, it is plunged into a cold mixture, the heat passes from it into the other, the fluid contracts, and falls. The height at which it stands indicates its temperature, and consequently that of the other body

with which it is surrounded, a scale being adapted to the tube. In applying a scale, it is necessary that it be so constructed, that the experiments made with one instrument should agree with those made with another. It has been ascertained that water freezes always at the same temperature, and that that at which it boils is uniformly the same, provided the pressure of the air does not vary. —*(See Evaporation.)* The parts at which the fluid will stand in a thermometer placed in water undergoing these changes, will therefore be always the same. These, then, are taken as fixed points in adapting a scale, and are termed the *freezing* and *boiling* points, the space between them being divided into equal parts, called *degrees.*

The thermometer used in this country is that recommended by FAHRENHEIT, a Dutchman, who divided the space between the freezing and boiling of water into 180 degrees, and conceiving that the greatest cold that could be produced was that of a mixture of salt and ice, he placed the commencement of the scale there; the freezing of water took place at 32 above this, the boiling point, being 180 more, was of course 212. Fahrenheit soon, however, found, that greater degrees of cold could be produced than that of a mixture of salt and ice; he was therefore under the necessity of extending his scale downwards. When, then, we speak of a temperature below the beginning of the scale, we say that it is so many degrees *below* 0, or the *zero*, as it is called. A shorter, and more convenient way of expressing it, is to add the word *minus*, or its algebraic sign —. Thus, minus 40, or — 40, signifies 40 below zero.

Other scales than that of Fahrenheit have been recommended, and though not in use in this country, are much employed on the Continent. Reaumur has divided his into 80 parts between the freezing and boiling points. One degree of this scale is therefore equal to $2\frac{1}{4}$ of F. *i. e.* 4 to 9. To reduce those of the one to the corresponding degrees of the other, the degrees of Reaumur must be multiplied by 9, the product divided by 4, and 32 added, because the commencement of the French scale is 32

above that of F. Thus, 60 R. $\times 9 = \frac{540}{4} = 135 + 32 = 167$; so that 60 R. = 167 F.

To reduce the degrees of F. to those of R. substract 32, then multiply by 4, and divide by 9. Thus, 194 — $32 = 162 \times 4 = \frac{648}{9} = 72$; so that 194 F. = 72 R.

Celsius of Sweden has adopted a much more natural division of his scale. He commences it at the freezing of water, and divides his interval between this and the boiling point into 100. Hence it is called the *centigrade* thermometer; 5 of C. are equal to 9 of F. of course the same rule must be followed in making the degrees of the one correspond with those of the other. Thus, 60 C. $\times 9 = \frac{540}{5} = 108 + 32 = 140$; so that 60 C. = 140 F.

Again, 185 F. — $32 = 153 \times 5 = \frac{765}{9} = 85$; so that 185 F. = 85 C.

The supposed accuracy of the thermometer has been called in question. It has been already said, that equal additions of caloric cause at different temperatures different expansions in fluids, and hence it is imagined by some, that the enlargement does not indicate the real temperature. The glass also of the instrument must expand a little, which is likewise supposed to cause a different expansion to appear from what really takes place. Mr Dalton, (Chem. Phil.) supposing that it follows the law laid down by him, viz. that it is as the squares of the addition of caloric, says that the degrees on the lower part of the scale are too large, while those at the upper part are too small. According to him, suppose 32 of F. to agree with 32 of his scale, 127 of the former is equal to 142, 151 to 162, and 199 to 202 of the latter. As we descend, the difference is still greater. Mercury freezes at — 40 F. while, according to Dalton, it ought to be — 175.

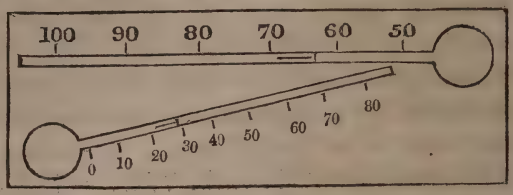
According also to De Luc, (Recherches, vol. i.) the expansions in the thermometric fluid are not uniform. Thus, in one experiment in which equal quantities of ice

cold and boiling water were mixed, a mercurial thermometer did not indicate the mean 122, but 119, from which it would appear that the mercury did not expand according to the addition of heat. This has induced him also to give a scale, in which the apparent expansions, as indicated by a thermometer, are compared with what he supposed to be the real ones. According to him, taking 32 as fixed points in each, 77 F. = 79.5 of De Luc, 122 = 125.15, and 167 = 169.16.

Though De Luc and Dalton have supposed that the expansions indicated by a thermometer are so very different from what they ought to be, Dr Ure, and Dulong and Petit, have on the other hand asserted, that they are by no means so great as has been supposed. The former has shown, (Ph. Tr. 1818), that though there is a slight difference, yet it is in a great measure compensated by the quantity of mercury in the ball always diminishing as we continue the addition of heat; and the latter have found in their experiments, (An. of Phil. xiii.) that from —40 to 212, it is scarcely appreciable. We may therefore consider the thermometer as an exact indicator of temperature, or at all events, as accurate as we can possibly expect it.

Different methods have been recommended for ascertaining the highest or lowest temperature that may occur at any particular period, as during night, when there is no one present to observe it. The instruments used for this purpose are called *Register thermometers.* The simplest contrivance of this kind is that of Dr Rutherford of Kinross. It consists of two thermometers, a spirit of wine and a mercurial one; the former for ascertaining the lowest, and the latter the highest heat. Into the tube of the former is placed a small piece of white enamel, which, as the fluid contracts, is brought along with it, but, on its again expanding, is not taken with it, it is left at the place to which it was carried, and thus the lowest temperature that had happened is pointed out. Into the tube of the latter is placed a small piece of a needle, so as just to rest on the mercury. As the fluid expands, it

pushes the needle before it, and on again contracting, it leaves it at that part to which it had carried it, so that in this way the highest temperature is ascertained. These thermometers



are fixed on a board, with the balls at opposite sides, the mercurial one horizontally, the spirit of wine one with the ball inclined downwards, so that, when we wish to set them, by raising the side next the spirit ball, the enamel and needle will come to the surface of the fluids.

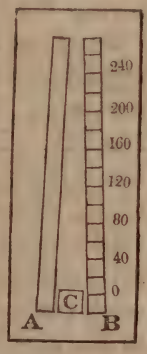
By the thermometer alone we are enabled to ascertain temperature, our sensations giving us no indication whatever; for a substance that feels warm to one, may feel cold to another, and different bodies, though of the same heat, may communicate very different sensations to the same person. Thus, iron will feel much colder than wood. That our sensations do not inform us of temperature, is proved by a simple experiment. Take three basins, put into one warm water, into another cold water, and a mixture of both into the third. Place one hand in the cold, and another in the warm fluid, and then put them both into the mixture. It will feel warm to the one and cold to the other, because its temperature is above that of the one, and below that of the other.

It must not be supposed that a thermometer is an exact measure of the number of degrees of heat in a body, it points out only the *relative number*. Thus, a substance at 50 is not supposed to have only 50 degrees of heat. It means, that it has 50 more than one at zero. Again, a body at 100 is not supposed to be twice as warm, or to contain twice as much heat, as another at 50, it has only twice as many degrees, reckoning from the commencement of the scale. If we knew the point at which there is absolute cold, in other words, where there is not any heat, and could begin the scale there, then the thermometer would indicate accurately the caloric—but of this we

know nothing. We must consider this instrument, then, as pointing out only the difference between the temperature of bodies.

The thermometer already described is of very limited application. By spirit of wine, the greatest cold may be measured, but owing to the low temperature at which it, and even mercury, pass into vapour, high degrees of heat cannot be ascertained; so that other methods have been resorted to for this purpose.

Many are in the custom of judging of intense heat by the appearance of the object. Thus, we have a dull red, a bright red, a white, and a full white heat. Sir Isaac Newton used to determine the heat by the rate of cooling, assuming that bodies lose caloric in proportion to the excess of their temperature above that of the surrounding medium. These methods, however, give very imperfect indications of temperature. Instruments have therefore been invented for measuring it, and which are called *pyrometers*, (πυρ, *fire*, and μετρον,) as being measurers of the temperature of objects brought to a heat equal, or superior, to that of a fire. That long in use for this purpose was invented by Wedgewood. Pure clay, and the earthy bodies in which it predominates, have the remarkable property of contracting, instead of expanding, by heat, and as the contraction is permanent, Mr Wedgewood conceived, that by measuring it, it would prove an indication of the heat to which the clay had been subjected. His pyrometer consists of two brass bars A B, fixed on a plate of metal, the space between them being smaller at one end than the other. They are divided into 240 degrees, corresponding to 31,200 of Fahrenheit's scale, so that each degree of the former is equal to 130 of the latter, and the beginning corresponds with 1077. In finding the degrees of the thermometer equivalent to those of the pyrometer, we must multiply by 130, and then add 1077. Thus 60 of Wedgewood is equal to 8877 of Fahrenheit.

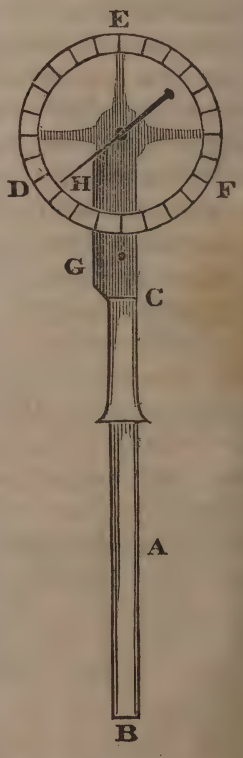


$$(60 \times 130 = 7800 + 1077 = 8877)$$

In reducing those of Fahrenheit to those of Wedgewood, we have first to subtract 1077, and divide by 130. Thus, 9668 Fahrenheit = 66 Wedgewood.

$$(9668 - 1077 = \tfrac{8582}{130} = 66)$$

The substance used as an indication of the heat is a piece of clay, made just to enter at the wide end, between the bars C. To ascertain the temperature of any object, suppose a fire, it is put into a crucible, and exposed to it for some time, and when cold, it is pushed on as far as it will go between the bars. Suppose it stops at 60, it shews that it has been subjected to a heat of 8877 of Fahrenheit.

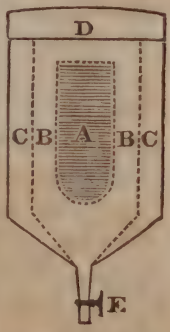


It was at first imagined that this would be of great utility in ascertaining high temperatures; from the difficulty, however, of procuring clay of uniform contractile power, it is not much used; besides, it is liable to one great objection. If the clay be exposed to a moderate heat for a long time, it will contract nearly as much as when heated intensely; it is necessary, therefore, to bring it as quickly as possible to the same temperature as the fire.

Another instrument now much employed for measuring high temperatures, is that rcommended by Daniells. It consists of a tube of black lead, A, shut at B, but open at C, where it is fixed to a brass tube; there is a bar of platinum in it rivetted at B, and at C having a small platinum wire passing from it, to the axis of the wheel D E F, and attached to a slight spring G H. The wheel, D E F, is connected with another, which has fixed to it an index, so that, when the tube is

heated, the platinum expands, and moves it. On the wheel is a scale containing 360 divisions, each of which is equal to 7 of F. so that the degree indicated by the Pyrometer, must be multiplied by 7, and it gives the corresponding one of F. Thus, tin melts at 92 of D, which multiplied by 7 = 644 of F.

There is still another method practised, for ascertaining high degrees of heat; it is that pointed out by Lavoisier and Laplace. Ice, in becoming water, absorbs a certain quantity of caloric. Now, by placing a heated body near it, and ascertaining how much of it is liquefied, the caloric given out may, it is supposed, be ascertained. Lavoisier and Laplace calculated that one pound during liquefaction, absorbs as much heat as would raise the temperature of the same quantity of water 135. The instrument employed by them for measuring the ice liquefied, is called a Calorimeter. It consists of three vessels, one within the other, with interstices between them. The inner one A is a cage for holding the body, the temperature of which is to be ascertained. The middle one B is for containing the ice to be melted, from the bottom of which there proceeds a tube and stop-cock E. The outer one C is likewise stuffed with ice, to prevent caloric being communicated from without to that in the centre; D is a lid which is also filled with it, to act in the same way. When the experiment is to be made, the middle and outer vessels being filled, the water in the interstices is drawn off from the former through the cock E. The warm object is then put into the cage, and the lid, also filled with ice, is put on. During the cooling down to 32, it must give forth caloric, which liquefies part of the ice. When this is done, the water is drawn off and weighed, and according to the quantity procured, the caloric absorbed is ascertained, and the temperature of the object when put into the cage inferred. This instrument appears at first sight well fitted for the purpose for which it



is intended: it is liable, however, to objections. It is difficult, nay, almost impossible to procure all the water that is formed, so much of it remaining in the pores of the ice; besides, it has been shewn by Mr Wedgewood, that the processes of thawing and freezing are actually going on at the same time in different parts of the middle vessel, some of the water formed in the upper part freezing in its passage through the ice beneath. This, he found, took place particularly when small objects were put into the inner cage. When, on the contrary, the body was large, little of the fluid was retained. The water obtained, therefore, was not uniform in the different trials, even though the substances were of the same temperature. Another objection, and one which does away with the value of the calorimeter, is, that the ice melted depends not so much on the temperature of the hot object, as on the *quantity of caloric* it gives forth during its cooling. It will be afterwards shewn that bodies, though at the same temperature, contain very different quantities of heat, they must of course emit it in proportion, so that those which have most, must produce the greatest liquefaction; and hence probably the discordance in the results of the experiments made with the calorimeter, with the view of ascertaining temperature.

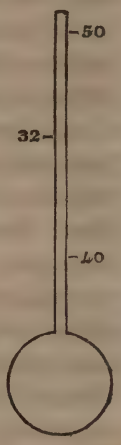
Before finishing the subject of expansion, we have yet to notice the exceptions to this law. When pure clay, or any substance containing it in considerable quantity, is exposed to heat, it contracts instead of expanding. As, in this case, the clay does not regain its original bulk when it cools, it is not to be considered a *real* exception; for, were it so, it ought to contract by heat, and expand by cold. Many bodies, in passing from fluid to solid, enlarge, even though they are parting with caloric, as is remarkably the case with water, ice occupying more space than the fluid from which it is formed. That it does so, is proved by putting water into a flask, marking its height, and plunging it into a mixture of ice and salt. In the course of a short time, the fluid will begin to congeal,

and the water will rise in the neck of the vessel, owing to the expansion of that which has congealed. That water expands while freezing, is also proved by ice always floating on it, shewing that bulk for bulk it is lighter than it.

The force exerted by the enlargement of water, while freezing, is astonishing, vessels, though made of metal, being easily burst by it; hence the cause of the frequent bursting of pipes during winter, the water, when freezing, expanding with such force, as to tear asunder the lead of the pipe. This points out the necessity of laying them a considerable way under ground, to prevent the frost from reaching them. Experiments have been conducted, with the view of ascertaining the actual force of the expansion. In one of these performed by the Florentine Academicians, (Ph. Tr. 1670,) a brass globe, having a cavity of an inch in diameter, was burst, by filling it with water, plugging up the mouth, and freezing the fluid, to accomplish which, it was calculated that the force exerted must have been equal to about 27,720 pounds. In an experiment of Major Williams, (Ed. Ph. Tr. ii.) a bomb filled with water was put into a cold mixture, to cause the fluid to freeze, and during congelation, an iron plug with which the aperture was stopped, upwards of two pounds in weight, was projected from its orifice to the distance of 415 feet, moving with a velocity of 20 feet in a second. Though this property of water is a source of great inconvenience, yet, in the economy of nature, we find it serving the most useful purposes. During winter, the moisture in the earth being frozen is expanded, by which it separates it sufficiently to permit the extension of the roots when vegetation begins.

The exceptions mentioned are not to be considered *real*, the substances having undergone a change; the clay has lost moisture, or some other matter, and the water has passed from fluid to solid. There is one real deviation, however, in the case of water at a certain temperature. When we apply heat to it at 32, instead of expanding, according to the general law, it contracts, and it continues to do so till it reach about the 40th de-

gree, after which, still continuing the heat, it begins to enlarge. On the contrary, when we apply cold to it at 40, instead of contracting, it actually expands, and continues to do so till it is frozen. The change in volume is not great, being only about 1-10,000th part, but it may be shewn by having the water in a small tube, with a ball at one end. Thus, suppose we put water at 50 into a tube of this shape, and plunge the ball into ice; as we withdraw the heat, it falls in the stem, till it comes to 40 or thereabouts. After this, instead of continuing to sink, it begins to rise; and when at 32, it is higher in the tube than 40; it must therefore have expanded. If, as when it is at this temperature, we heat the ball, the water, instead of rising, did it follow the usual law, falls in the tube, so that at 40, it is lower than when at 32; it must therefore have contracted. From this it is evident that water at 40 is of greater density, that is, bulk for bulk it weighs more, or is of greater specific gravity, than at 32.



This very remarkable property of water was first noticed by the Florentine Academicians, but it was afterwards denied by several eminent chemists, who supposed it to be a deception occasioned by the irregularity in the enlargement and contraction of the vessel containing it. It has now, however, been proved by the most satisfactory experiments. Sir Charles Blagden endeavoured to prove it by ascertaining the density at different temperatures, (Phil. Tr. 1792.) He weighed equal bulks of water at 32 and at 39, and he found the latter to be of greater specific gravity than the former, which it ought not to have been, had it followed the usual law in contracting to 32, or the point of congelation. Thus, if heat be applied to water at 32, it ought, provided it was not an exception to the general law, to expand; and as the same bulk would contain less matter than before, its specific gravity should be diminished. It ought therefore,

at 39, to be of less specific gravity than at 32. This, however, according to Blagden, is not the case. He found that the density was greater at 39, proving, that by the addition of caloric, instead of expanding it must contract.

This anomaly of water has been still more satisfactorily proved by the experiments of Dr Hope, (Ed. Phil. Tr. V.) It has been already mentioned, that by applying heat to fluids, currents are induced, by which the caloric is conveyed through them, the warmer particles, owing to their expanding, becoming of less specific gravity, and ascending, while the colder particles fall. In his experiments, Dr Hope took a tall jar, in which two thermometers were suspended, one at the top, the other at the bottom; round the middle of it was placed a pan, into which either a warm or cold mixture was poured as required. He first filled the jar with water at 32, and put a fluid of temperature 68 into the pan. As the water became warm, the particles, instead of rising, actually fell, and affected the thermometer, while that at the top did not suffer any change. This current of heated particles *downwards*, went on till the instrument below rose to 39.5, after which, that above began to be affected. In another experiment, he filled the jar with water at 39.5, and put a cold mixture into the pan. As the fluid parted with its caloric, the cooled particles, instead of *descending*, actually *rose*, and affected the thermometer at the top.

Though it has thus been proved that water is a remarkable exception to the general law of expansion, during a certain range of temperature, yet the degree at which this commences has not been determined. Blagden, it has been said, placed it at 39, Dr Hope at 39.5, and Rumford, who has made experiments on the subject, considered it very nearly the same, (Nicholson's Journal, Aug. 1805.) Mr Crichton of Glasgow has lately fixed it at 42.3, (An. of Ph. N. S. v.) His experiments were performed by putting a hollow glass ball at the bottom of a jar of water at 32, and applying heat, by which, as the density became greater, the ball began to rise, and con-

tinued at the surface till it again changed, that is, till it began to expand, after which it immediately sank. By marking the degree of a thermometer placed in the water while undergoing these changes, and taking the average of a number of trials, he has placed the greatest density at 42.3, so that, according to him, water from 32 to 42 contracts, while from 42 to 32 it expands.

This remarkable deviation from the general law, is ascribed to a new arrangement of the particles. It has been already said, that water expands during congelation, which, it is supposed, is owing to the particles assuming a particular arrangement, the spiculæ of ice on the surface always darting out at a certain angle from the sides of the vessel, or from each other. This, it is imagined, may begin some time before congelation occurs, and thus, though caloric is withdrawn, give rise to the expansion. The important results of this deviation will be afterwards noticed.

Communication of Caloric.

It has been already said, that heat has a tendency to pass from one body to another, till they become of the same temperature. Thus, if a warm substance be placed near a cold one, the heat passes from the former to the latter, till the temperature of both is the same, which has been ascribed to the repulsive nature of the particles of caloric, which it is supposed have a tendency to recede from each other. It is not, however, entirely owing to this, for, if it were, it ought to pass with equal celerity from all objects, which is by no means the case. The quickness with which it is given off is much influenced by the nature of the body, and the difference of temperature between it and the cold medium. A substance is cooled more quickly in air than *in vacuo*, and more so in water than in air. It is now known that heat is transmitted in two ways. If a hot object be placed in contact with a cold one, the caloric passes *slowly* from the one to the other. When, on the contrary, it is sus-

pended in the air, it darts off from it *quickly* to the surrounding objects. In the former instance, it is said to be *conducted;* in the latter, to be *radiated*. This necessarily divides the communication into two parts,—the conduction, and the radiation.

Conduction.

All bodies can receive heat, yet they do so with different degrees of celerity. If a piece of iron and of wood be placed near a fire, the iron will be sooner heated than the wood; the same is the case with their rate of cooling, the former parting with its caloric more quickly than the latter. This property of bodies to receive and give it out, is called their *conducting power*, and those which receive it, or part with it, *quickly*, are termed *good conductors*, while those which receive it, or part with it, *slowly*, are termed *bad conductors*. Though substances take in and give out heat differently, yet each receives and parts with it in the same degree. Thus, in the example of the iron and wood, the former becomes much sooner heated, but it is also sooner cooled than the latter. Those bodies, then, which receive heat quickly, also part with it quickly, and those which receive it slowly, part with it slowly.

If a rod of iron be put into a fire, the end in the fuel will soon become red hot, and the caloric will pass so speedily from particle to particle, that the hand cannot bear the heat of the opposite end. A small piece of wood, on the contrary, though burning at one end, may be taken hold of at the other with impunity. In the former instance, the metal is said to be a good conductor, or to communicate the heat quickly from particle to particle. In the latter, the wood is said to be a bad conductor, or to convey it slowly. Bodies, then, conduct heat very differently. In general, the denser the substance, the better is its conducting power. Metals, the densest bodies with which we are acquainted, conduct it quickly, while wood, earthen ware, woollen cloth, and fur, do so very slowly.

That bodies conduct heat differently, may be shewn by a very simple experiment. Put a lamp under the centre of a sheet of copper, and, at the corners place a piece of iron, I, tin, T, lead, L, and stone, S, of the same size and thickness, and having on each a small bit of phosphorus. That on the iron will be first kindled, shewing that it is soonest heated; in other words, that the caloric has passed most quickly through it. Next will come the tin, then the lead, and lastly, the stone, the phosphorus on which will remain a long time.



Richman has made several experiments on the conducting power of metals. He inclosed the bulb of a thermometer in hollow metallic balls, and plunged them into boiling water till the thermometer stood at the same height in each. He then exposed them to the air, and observed the time they took to come down to a certain degree. The ratio in which the metals lost caloric was as follows:

Brass 10,	Iron 11,	Lead 27.
Copper 10,	Tin 17,	

Hence he inferred, that of these brass and copper were the best, and lead the worst conductor.

Ingenhouse followed a more simple method. He took wires, and coated them with wax of the same thickness to the height of eight inches. He then plunged them two inches deep into warm oil, and according to the length of wax melted, he inferred the conducting power. He found that silver was the best, next came gold, then tin and copper, which were nearly equal. Platinum, steel, iron, and lead, were inferior, lead being the worst, (Journ. de Phys. xxxiv.)

The method followed by Rumford, in ascertaining that of materials used for clothing, was extremely simple. (Essays, Vol. II.) He had a hollow cylinder of glass with a ball at one end, in which was suspended a ther-

mometer surrounded by the substance to be tried. The cylinder was then plunged into boiling water till the thermometer arrived at a certain temperature, after which it was removed, and put into ice and water, and from the time it took in reaching that of the mixture, he inferred the conducting power. The time required for cooling the thermometer being expressed in minutes, of course the conducting power is inversely as the time. Air 576, fine lint 1032, cotton 1046, wool 1118, raw silk 1284, beaver's fur 1296, eider down 1305, hare's fur 1315. With wood ashes, the time required was 927, with charcoal 937, and with lamp black 1171.

From the knowledge of the conducting power of bodies, many useful hints are derived. When we wish to keep a substance warm, we surround it with a bad conductor, or one which allows the heat to be slowly transmitted through it. To preserve ourselves warm, we are covered with bad conductors, as woollen cloth, fur, &c. This has given rise to the idea, that these actually possess warmth, which is not the case. They merely prevent the air, which is colder than our bodies, from quickly taking caloric from them. In India, when ice is procured, it is instantly put into blankets, which serve the same purpose as our clothing, by preventing the caloric from being transmitted from the warm air to the colder ice.

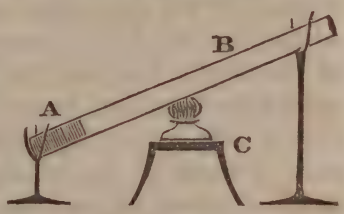
On the contrary, if we wish to warm a body quickly, a fluid for instance, we put it into a vessel which is a good conductor, as a metallic one.

It has been already said, that the sensations of heat and cold, communicated by different bodies, are different, even though of the same temperature. Thus, if we put our hands on a piece of metal and wood, a little heated, the iron only will feel warm. If they be colder than the hand, the iron will feel cold, while the wood will communicate a sensation very little different from what it did before. This is accounted for by the difference in their conducting power. In the first instance, the iron,

being a good conductor, gives off its heat quickly to the hand; whereas, the wood, from its being a bad conductor, parts with it slowly. In the latter instance, the iron takes heat from the hand, and quickly transmits it from particle to particle, so that, in a given time, it robs it of a great deal; whereas the heat given by the hand to the wood, owing to the inferior conducting power, remains long near the surface. The hand, therefore, being suddenly deprived of heat by the iron, feels cold; but the abstraction by the wood being gradual, little or no particular sensation is perceived.

What has been said of the conducting power of bodies, and of the communication of heat through them, relates only to solids. The effect is very different with respect to liquids. *In them heat is transmitted quickly or slowly, according to the method in which it is applied.* In solids, it is communicated from particle to particle, till the whole is warmed. When, on the contrary, we apply it to the *bottom* of a vessel, with a fluid, the particles below, as they acquire it, expand, become lighter, and ascend, the colder ones fall, gain caloric, and rise, so that the fluid is not warmed by the heat being *communicated* from particle to particle, as with solids, but by its being *conveyed* through it by the currents. We would imagine, from the ease with which fluids are warmed in this way, that they are good conductors; they are, however, quite the reverse, as has been proved by the experiments of Count Rumford. Rumford was first led to suppose that fluids are bad conductors, from finding that decoctions of vegetables, as stewed apples, which contain a large quantity of water, retain their heat for a long time. His experiments were performed under a variety of cirumstances. In some he gave full play to the currents, while in others they were interrupted by placing substances, as eider down, in the fluid. If, for instance, a piece of ice, loaded, be placed at the bottom of a jar, and over this be poured cold water, to the depth of about an inch, and

again, above this, boiling water, put in very cautiously, to prevent it mixing with that beneath, the ice will continue for a long time unmelted, proving the very bad conducting power of the cold fluid. In this experiment, there are no currents to convey the caloric to the ice. The bad conducting power of fluids he proved in another way, and perhaps still more satisfactorily, by putting at the bottom of a tube a piece of ice loaded, A, pouring in cold water, B, and applying a lamp, C, to about the middle of it, to cause it to boil. In this instance, the ice will remain for a long time, though the water, at the distance of a few inches, is kept boiling; and here also the currents do not operate, so as to affect the ice; for though the heat is applied to the middle, the particles, as they are warmed, ascend, while the others fall, but only as far as the flame, where they are to gain heat, and rise.



If, on the contrary, a piece of ice be put on the surface of warm water, it is almost instantly melted, because it is constantly washed by warm particles, those at the top, as they give out heat, contracting and falling while the warmer ones rise to occupy their place.

Rumford pointed out another very curious fact with regard to the conducting power of fluids. He found that when water at 40 was placed between the ice and the warm liquid, the liquefaction went on more slowly than when water at 32 was used. This is accounted for by the anomaly already explained, (page 24,) that it is specifically heavier at 40 than at 32. When, therefore, water at 40 is poured over the ice, the particles, as they receive heat from the fluid above, ascend: Whereas, when it is at 32, as it contracts by the acquisition of caloric, it falls, comes in contact with the ice, and melts it; and this current of the heated particles downwards, goes on till

the whole of the cold water is brought up to 40, after which the warm particles begin to rise.

These different experiments led Rumford at first to conclude, that though fluids can receive caloric from other bodies, yet they cannot communicate it from particle to particle; an opinion, however, which he was afterwards induced to relinquish. When a fluid was warmed by the application of heat to the top, he supposed that the caloric was conveyed entirely along the sides of the vessel; but that this is not the case, has been disproved by numerous experiments, more particularly by one of Dr Murray, (Nicholson's Journ. Vol. I.) He took a vessel of ice which never could have its temperature above 32, and filled it with different fluids, a delicate thermometer being suspended at the bottom. By applying a heated body to the surface, the thermometer was observed to rise. In this instance, then, the heat must have been conveyed, not by the vessel, but by the fluid, having been transmitted from particle to particle.

It is difficult to ascertain the conducting power of fluids, as it is not easy to find what is due to conduction, or to the transportation by means of the currents, and no very satisfactory experiments have been made on the subject.

Rumford held the same opinion with respect to aerial fluids, that he did with regard to liquids. His experiments have proved their bad conducting power, and that the communication of heat through them depends almost solely on the currents, which being impeded, the communication is retarded.

That heat is conveyed through air in the same way as through fluids, is proved by an experiment already mentioned. Let a person hold a red hot poker horizontally, and let another place his hands, one above, another below it, the former will be much more heated than the latter, because the particles of air in contact with the poker, by acquiring caloric, expand, and

rise. On the contrary, if a piece of ice be held in the place of the poker, the hand beneath is most cooled, because the particles that touch the ice, by losing heat, contract and fall, and therefore reach the hand below. It is owing to the currents induced in air, by an application of heat, that the popular but erroneous idea has originated, that caloric has a tendency to ascend. It does not rise of itself; it is carried up by the warm air.

From what has now been said of the conducting power of fluids and air, and of the mode by which heat is transmitted through them, many useful practical lessons may be derived, particularly with respect to the economy of fuel. Thus, when we wish to warm a fluid, it must be heated from below, otherwise it will be very slowly warmed; for, if the heat be applied from above, the surface only receives caloric, the warm particles remaining at the top. In throwing heated air into a room, with the view of warming it, the pipes ought to open as near the floor as possible, to allow the air to rise, and thus communicate caloric to the whole of that in the apartment. In heating fluids by steam, the mouth of the pipe from which it issues, ought always to be near the bottom of the vessel, that the particles below, as they acquire heat by the condensation of the vapour, may expand and rise, and allow those above to fall, in their turn, to gain heat, by which the whole of the fluid may be quickly warmed. Were the pipe to terminate near the top, the particles there would soon become so warm, that they would cease to condense the steam; in fact, the fluid above would be actually boiling, while that at the bottom would be quite cold.

The currents in fluids and airs serve important purposes in the economy of nature. Thus, though ice is formed in small collections of water, the adjacent lakes may not be frozen; and there are many accounts of lakes never freezing, which has been ascribed to their having warm springs in them. It is to be accounted for, however, by the currents induced by a change of temperature. Suppose a lake at 50, and cold is applied to the

surface, the cooled particles descend, and the warmer rise, by which the whole of the water must be brought to a certain temperature ; but our common frosts do not continue long enough to do this, consequently, large lakes do not freeze. On the contrary, in pools, though the cold applied to the surface is the same, the fluid is soon cooled to the proper pitch, and ice is formed.

The whole of the water, it has been said, must be cooled to a *certain temperature ;* it is not necessary, however, that it must be all brought down to the freezing point. Owing to water, at a certain degree, being an exception to the general law of expansion, when that in a lake is cooled to 40, by the farther abstraction of heat, the particles on the surface do not contract ; they expand, and remain above, so that they are brought to the 32d degree, and freeze, while the water below is still at 40, and continues nearly so ; for the ice being a bad conductor, the heat is slowly abstracted through it. Large lakes, then, not only seldom freeze, but if they should, ice is formed only on the surface. Had not Nature deviated in a remarkable degree from the general law of expansion, at the temperature mentioned, the whole would be frozen when properly cooled, and thus prove destructive to the life of its inhabitants.

The preceding remarks apply to lakes, or large rivers only. In small rivers the whole of the water is generally of the same temperature, for though that at the top, when cooled to 32, is of less specific gravity than the rest, it does not remain on the surface. Owing to the agitation of the water, and to wind, particularly when blowing in a direction opposite to the current, it is mixed with that beneath. Hence it is, that we have often ice formed first at the bottom, the pebbles and other objects there, affording nuclei, on which it is deposited when the temperature of the whole is brought to 32.

It has been mentioned that these movements take place in gaseous fluids. There is, however, one apparent exception to this in the air of the atmosphere, which, as we ascend, becomes colder, till we at last arrive at perpetual

frost. This, however, is easily accounted for. The air below, as it receives heat from the earth, is expanded, and becoming specifically lighter ascends, but it rises only to that height where it meets with air of the same rarity with itself, occasioned by the diminished pressure, to which in the higher regions it is subject; so that the upper particles, being always free from much pressure, remain above, and though the sun's rays pass through them, yet they do not communicate any warmth to them. In confined portions of air, on the contrary, the warmest part is always above, but in this case, that at the bottom and at the top sustain very nearly the same pressure; so that this does not interfere in the movements of the particles.

The distribution of heat over the globe is in a great measure regulated by the currents in fluids, and in the atmosphere. Thus, the earth being warmed by the sun's rays, imparts caloric to the air immediately over it, the particles of which ascend, and cold ones supply their place, so that, though it is constantly receiving heat, yet it is also constantly parting with it. As that part of the globe at the Equator is warmest, the air over it is much heated, and rises, so that there is a continual cold current from the North and South Poles towards it, and corresponding warm ones from the equator to the poles, by which the intense heat of the former, and severe cold of the latter, are moderated.

The currents in fluids serve the same useful purposes. When a cold wind passes over the surface of water warmer than itself, it receives heat from the particles above, which, as they become cold, descend, and have their place supplied by others, also to give off heat. By this means there is a constant supply of warmth to the air, and the cold is diminished. Hence the comparative mildness of islands surrounded by a great extent of ocean, as is the case with Great Britain, the temperature of which is far above that of inland countries in the same latitude; the wind which reaches the former receiving heat from the water, whereas that coming to the latter,

flowing over the earth, which is a bad conductor, receives little from it. Thus, in many parts of the Russian dominions, in the same latitude as that of Britain, mercury is often frozen during winter, so that the thermometer must be at least —40, whereas here it is rarely so far down as 10, almost never to 0.

Radiation.

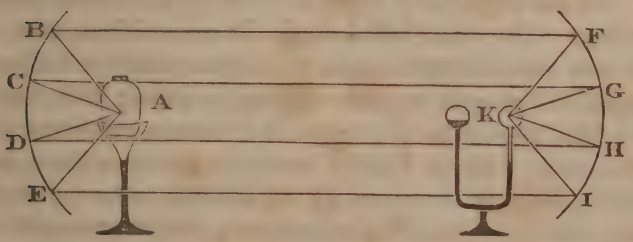
When a warm object is suspended in the atmosphere, the caloric flies off from it to the surrounding colder bodies with great velocity. If a person place his hand before a hot substance, with a screen between them, he is not warmed, but the moment the screen is removed, he is sensible of the heat. This shews the quickness with which it passes through the air; and from its flying in all directions, it is said to be *radiated. The rays that thus dart from warm bodies, may be reflected and concentrated into a focus.* Thus, if a person stand at the side of a fire-place, he is not warmed; but if a polished plate of metal be held opposite it, the rays passing from the fire, and striking the plate, are reflected, and if properly directed, will reach the person, and warm him.

The first mention that is made of radiation of caloric, is by Mariotte in 1682 (Mem. of Acad. of Science,) and it was soon afterwards noticed by Lambert (Voyage dans les Alpes par Saussure.) They shewed that caloric passes through the air from a burning body, and warms the objects on which it strikes. Scheele (Treatise on Air and Fire,) repeated the experiments of former chemists, and pointed out many new facts concerning it. He shewed that the heat thus given off, passes through the air without warming it, and that wind has no effect in changing its direction. He also observed that the rays were reflected by some bodies, yet absorbed by others. Saussure and Pictet (Essais de Physique —) confirmed the experiments of Scheele, and Herschell, Leslie, and Rumford, have greatly extended our knowledge on this important subject,

(Leslie's Inquiry into the Nature of Heat.—Rumford's Essays.—Herschell, Phil. Tr. 1800.)

To illustrate the different facts concerning radiation, polished metallic concave mirrors are employed, some of which are sections of an oval, others of a circle, or an ellipse. If they be placed opposite to each other, at the distance of several feet, a cage of ignited charcoal near one will instantly affect a thermometer in the focus of the other. There is no necessity, however, for having recourse to so delicate an indication of the heating effect; for if a piece of phosphorus be held in the focus, it is instantly kindled.

In these experiments, there must be something emanating from the charcoal, which is reflected by the mirrors, and concentrated also in a focus, so as to set fire to phosphorus. When, then, the charcoal, A, is placed near the mirror, rays of heat fly off from it in straight lines, A B, A C, A D, A E, to the mirror, by which they are instantly reflected again in straight lines, B F, C G, D H,



E I, to the opposite one, where they are also reflected at F K, G K, H K, I K. They are thus brought to a point at K, where the heating effect is produced. The distance at which this takes place, depends of course on the form of the mirror. If, instead of burning charcoal, we make use of a red hot iron ball, the same is produced, though the effect is not so great, the temperature of it being less than that of the other.

In these experiments, the effect on the thermometer differs according to the distance of the mirrors from each

other. By the law laid down, it decreases as the squares of the distance, that is, if at 2 feet it be 4, at 4 feet it is only 1.

Some objects have the power of absorbing, others of allowing the rays to pass through them. Thus, if a pane of glass be placed between the mirrors, the heating effect is not produced, because it retains the rays. It is owing to this that we can look through glass at a strong fire, or furnace, without hurting the eye, the rays thrown off being prevented from reaching it. Other bodies, on the contrary, reflect the rays. Thus, if we cause them to strike on a polished one, it is little heated. If a differential thermometer, with its ball gilded, be put into the focus of one mirror, the cage of charcoal into the other, there is very little effect on it, the rays that strike it being instantly *reflected*. On the contrary, if the other ball be blackened, and placed in the focus, the change is much greater, the blackened surface *absorbing* the rays. Some surfaces therefore absorb, while others reflect the radiations of heat.

The above remarks apply to burning and incandescent bodies. The same, however, is the case with substances not incandescent; these also, if their temperature be above that of the atmosphere, are constantly giving forth heat; and that they do so is proved, by placing any warm object, as a flask of boiling water, near the mirror; the thermometer in the focus of the other is instantly affected, thus proving, that all objects, the temperature of which is above that of the contiguous ones, are constantly sending off radiations of caloric, and which, it is generally allowed, is the material agent in its pure disengaged state, subject to the laws of reflection and concentration like other radiated matter.

Having made these preliminary observations, we have now to state more particularly the different facts concerning radiation. The power of radiating is proportional to the difference between the temperature of the hot body, and the surrounding medium, and also to the *extent* of surface.

The most remarkable circumstance, however, is the effect of the *nature* of the surface. It has been ascertained, by numerous experiments, that the more resplendent the surface, the less is the radiation; and on the contrary, the darker and rougher it is, the radiating power becomes the greater. The effect of surface is well illustrated, by putting different flasks near the mirror. If a resplendent one be filled with boiling water, and put near it, the thermometer is very little affected; but if the same flask have its surface smoked, the effect becomes much greater. The power of radiating has been well illustrated by the experiments of Leslie. He took a cannister of tinned iron, covered one side with smoke, a second with paper, a third with glass, and left the fourth resplendent. It was filled with boiling water, and placed with its different sides towards the mirror. Considering the effect of the black side on the thermometer as 100, that of the paper was 96, of the glass 90, and of the resplendent metallic one only 12; so that blackened objects produce about 8 times as much effect as resplendent ones.

It has been already remarked, that bodies receive the rays very differently. The experiments with the differential thermometer already mentioned, shew that blackened bodies receive them very quickly, while resplendent ones scarcely receive them at all; in other words, they reflect them. Those bodies, then, which are good radiators, are good absorbers; while those which radiate little, absorb little. Good radiators, therefore, are bad reflectors, and bad radiators are good reflectors.

From the fact that some bodies absorb while others reflect the rays of caloric, Leslie has contrived his *Thermoscope*, which is merely his differential thermometer with one ball made of black glass, the other gilded. The rays of caloric striking the balls, affect them differently; they are reflected by the gilded ball, and absorbed by the black, consequently the air in it will be expanded, and the fluid in the stem attached to it will fall. The

depth to which it sinks denotes the heating power of the rays.

Leslie has shown, that during the reflection and concentration of the rays of caloric, the greatest heat is produced, not in the focus, but nearer the mirror. A thermometer was raised one-third more when placed half an inch nearer the mirror, than when in the focus itself. On the contrary, when put beyond it, the effect was greatly diminished.

Screens of various materials have different powers of stopping the radiations. A screen of tin-foil, or even of gold leaf, which is 600 times thinner, completely intercepts them. A pane of glass, or a sheet of paper, apparently intercepts them only partially. It is said apparently, for at first sight it would appear that they did pass through; but Mr Leslie denies this, for if it were so, the effect ought to be the same at whatever distance the screen is placed from the hot body. This is, however, not the case; the nearer the glass is to the radiating surface, the greater is the rise of temperature indicated by the thermometer. The glass, he therefore supposes, first receives heat, and then itself begins to radiate; and that this is the case seems to be proved by the following experiment. He took two plates of glass, and coated each on one side with tin-foil: when they were put together by their glass sides, so as to expose the metallic surfaces, one to the radiating body, the other to the thermometer, the rays were entirely stopped. When the metallic sides were in contact, the thermometer was affected. In these experiments, then, the same substances were used as screens. In the first, however, surfaces were exposed, which receive and give out heat slowly, of course the rays coming from the hot body were almost all reflected. Those absorbed were but slowly emitted by the metallic leaf, which is a bad radiator. In the other instance, when the glass sides were exposed, it received the rays from the hot body, much more quickly than the tinfoil, and again, it also

gave them off more quickly, by which the thermometer in this instance was most affected.

The experiments of Delaroche (An. of Ph. ii.) are at variance with the conclusions of Leslie. According to him, radiant heat passes directly through glass, and the more the temperature of the object is elevated, the more easy is the transmission. Thus, by placing screens between the warm body and the thermometer, and by having these replaced by others, when their temperature was likely to be affected by absorption, he found that the thermometer rose, proving that the effect on it was not by radiation from the glass.

The preceding remarks apply to the emanation from bodies, the temperature of which is above that of the surrounding atmosphere. A question now occurs; does it cease to radiate when its temperature is the same as that of the medium? According to some it does. Prevost, however, supposes that it does not. He alleges that objects, though all of the same temperature, are continually giving out and receiving calorific emanations. Hence, if a substance give forth more than it receives, its temperature must fall.

From what has now been said, we see that heat is communicated in two different ways,—the one by slow communication from particle to particle,—the other by its darting through the air from the surface of one object to another. When, then, a hot body is placed in air colder than itself, both of these modes operate; but they do so very differently,—one losing most by conduction, another by radiation. Even the same substance, at different times, parts with its heat differently, according to circumstances. In general, that given out by the one method, is inversely to that lost by the other,—that is, when much is lost by conduction, there is little emitted by radiation; or, if much is given forth by radiation, there is little loss by conduction. Thus good conductors, for instance metals, are bad radiators. Spongy bodies conduct heat slowly, but they radiate powerfully.

The cooling and heating process is also much influenced by external circumstances; these refer both to the bodies themselves, and to the medium in which they are placed. To the former belong temperature, size, figure, surface, and the peculiar nature of the object. It is a general law, that the greater the difference of temperature between the hot body and cooling substance, the more quickly it loses caloric. Sir Isaac Newton laid it down as a general law, that as the times proceed in an arithmetical, the caloric lost is in a geometric progression. Thus, if in the 1st minute, the loss is 3°, in the 2d it is 9°, in the 3d 27°. Martine, on the other hand, (Essay on Heat) asserts, that as the temperature of the substance approaches that of the medium, the caloric given off is as the times; the body loses just as much in the first minute as it does in the second, and so on till the equilibrium is established. Leslie and Rumford have shown that the caloric given off is always the same, at whatever temperature the cooling is going on, provided the difference between it and the medium is the same.

The magnitude of bodies also affects their cooling. Thus, if we have two masses of the same matter, but of different sizes, the heat given out is not in proportion to the quantity of matter, but to the surface. Suppose we have an inch cube and two inches cube of the same substance, and at the same temperature, the latter contains eight times as much matter as the former, but it does not lose eight times as much heat,—it gives out only four times as much, because it presents quadruple the surface. It follows from this, that the figure must also affect the cooling, as it varies the extent of surface. If we have two objects of the same nature, that which exposes most surface, cools most quickly. A sphere, therefore, which presents least, cools more slowly than any other.

The effect of the nature of the surface in influencing cooling, has been already explained when detailing the laws of radiation. The darker and rougher, the more powerfully does it radiate; it must therefore cause an

object to cool more quickly. On the contrary, the more resplendent the surface, the less does it radiate; it must therefore make a body cool the more slowly.

The nature of the object itself also affects the cooling, more particularly with respect to its conducting power. A good conductor, as a metal, cools much more quickly than a bad conductor, as wood; because the heat which is carried off from the former, is soon supplied from the internal parts; whereas, in the latter, it passes slowly from within to the surface.

The cooling process differs, also, according to the nature of the substance by which the warm object is surrounded. The more heat it can receive, the more quickly is the other cooled. A substance, also, which is a good conductor, cools a body much more speedily than one which is a bad conductor, because the heat given off from the latter is quickly communicated from particle to particle, so that, in a given time, it loses a great deal. Thus, a hot iron cools more quickly in water than in air, and much sooner in quicksilver than in water,—water being a better conductor than air, and quicksilver better than water.

Air, it has been said, is a bad conductor, and cools a body slowly. If, however, by any means the particles which are heated be removed, and others made to supply their place, the cooling goes on more quickly. Hence the effect of wind in accelerating it; a substance being much sooner cooled during a breeze than when the air is calm, as is well exemplified in our own persons, a windy day always feeling colder than a calm one, though of the same temperature, because the wind carries off the warmer particles of air, and supplies others, which also deprive us of heat; whereas, in a calm atmosphere, the air that has taken heat from us is retained in a great measure among our clothes. Hence it is, also, that when carried quickly through the atmosphere, we feel so cold, as when driving in a gig, the air with which we are constantly brought into contact depriving us of heat,

while we have no exercise as a means of supplying the loss. Leslie has found that a flask of water cools four times as fast in a moderate steady breeze, as in a calm atmosphere, six times as fast when the breeze is strong, and fifteen times as quick in a hurricane.

From what has now been said, it is evident that the caloric lost by conduction and radiation, must be materially affected by different circumstances. A body, which at one time loses most by the former, may therefore, at another, give off most by the latter. Thus, a substance which, from the nature of its surface, parts with most caloric by radiation when placed in air, loses the whole by conduction when surrounded by a fluid. On the other hand, a body which radiates well gives off most of its heat in this way when suspended in a calm atmosphere, but when exposed to wind, it may lose most by the other, the wind not in the smallest degree affecting the radiation, but by carrying off the particles of heated air, and supplying others, accelerating the loss by conduction. Even though the air remains calm, the heat given out in these ways, may vary according to the difference of temperature between that of the body and the surrounding medium. Thus, if the temperature be little above that of the medium, few currents of air will be induced, and little caloric will pass off by conduction; whereas, when the difference is great, the currents will be more rapid, so that a great deal may be lost in this manner, the hot object being constantly exposed to a stream of cold air.

What has been said of the cooling, applies equally to the heating of bodies, for those which give out much heat by radiation, so as to cool quickly, receive it easily, so that they are soon heated; while those which radiate little, receive few rays, and are slowly warmed. On the other hand, those which cool quickly by giving out caloric by conduction, take it in quickly in the same way, and are soon heated; while those which conduct slowly receive little by conduction.

From the facts now stated concerning the communication of heat, and of the circumstances that influ-

ence the heating and cooling of bodies, many useful practical observations may be drawn. Water continues much longer warm in a resplendent than in a blackened vessel. Hence metallic ones, with their surfaces polished, are often employed for holding warm water, when we wish it to retain its heat for some time. It is a common remark, that tea is more easily infused in a silver than in an earthen tea-pot, which was at one time supposed to be owing to some property of the metal itself, but which is now accounted for by the laws of radiation, the bright metallic surface giving forth fewer rays than the other, and of course, cooling the water less slowly. A metal is, however, a good conductor; it is of advantage, therefore, to have not only a bad radiator, but also a bad conductor, that the heat given off from the surface by radiation may be slowly supplied from the interior. Hence the frequent use of earthen ware covered with metallic matter, for holding warm fluids, as for jugs and tea-pots, the earthen ware being a bad conductor, and, by having its surface resplendent, becoming also a bad radiator, by which little heat is evolved.

When, on the contrary, we wish to cool a fluid quickly, it must be put into a vessel which is a good conductor, as a metallic one, and with its surface blackened, to make it a good radiator. In conveying heated air, or steam, from one place to another, with the view of heating apartments, the tube ought to be made of bright metal, as tinned iron, that there may be little heat lost before the air reaches the place to be warmed. When, on the contrary, the steam is to be condensed, the tubes ought to be made of blackened metal, as sheet iron, so that a great deal of caloric may be given off, both by radiation and by conduction.

When we have to guard a body from heat, we cannot employ a better protector, than a plate of bright metal. Thus, in erecting a stove near wood-work, the latter ought to have a sheet of tinned iron placed near it, but not in contact with it, by which the greater part of the rays sent off from the stove are reflected. Should the

metal itself become warm, the layer of air between it and the wood, being a very bad conductor, prevents in a great measure the transmission of the heat. Should stone be employed as the protector, it must be whitened, so that it may absorb as few of the rays as possible.

Before finishing this subject, we may here take notice of some beautiful provisions of nature, for preventing too great heat or cold over the earth.

It has been shewn, that when a warm object is placed in air, it is constantly giving forth radiations. Could we suppose, then, an object to be sending off rays, without receiving any to compensate for the loss, it would become cold. And this is actually the case with the earth during night. The principal source of the earth's heat is the sun's rays, which, passing through the air without warming it, arrive at the earth, and are absorbed. During night this gives forth radiations, which fly up into the atmosphere; and, as it does not receive any in return, its temperature falls. By this fact, many curious occurrences of nature can be satisfactorily accounted for. It will be afterwards illustrated, that during the conversion of a vapour to fluid or solid, heat is disengaged. Dr Wilson of Glasgow, pointed out what was then thought a remarkable exception to this general law, in the deposition of hoar-frost and dew, which are merely the condensed watery vapour of the atmosphere.

It was observed in Glasgow, that a thermometer hung in the air was at —7, while one placed on the ground was so low as —23. This, however, was the case only when the air was calm, and the sky clear; when a cloud was passing, the temperature of the instrument on the ground instantly rose, but again sank when the sky was unobscured. The same occurred with rough bodies, as grass, and leaves of plants, the thermometer, when placed on them, indicating a much lower temperature than one hung in the air. When, however, the former was placed on a polished object, as a plate of metal, there was no difference, the temperature of both being

the same. It was found also, that though the thermometer on the ground was acquiring hoar-frost on its bulb, its temperature was considerably lower than that of the other, and on which there was no hoar-frost. Now this is the reverse of what should have happened; the watery vapour, during its conversion into hoar-frost, ought to have raised the thermometer; it appeared, therefore, to be a deviation from the general law. It has now, however, been proved by most satisfactory experiments, that this is not the case. By Dr Wilson, the cold was considered the *consequence* of the deposition. Dr Wells has, however, shewn that it precedes, and is therefore the *cause* of it. (Wells on Dew.) During a calm and clear night, a thermometer on the ground will be 12 degrees lower than one hung in the air, and which is occasioned by the earth radiating caloric, which passes off into the heavens; as there is nothing to return heat, its temperature, and consequently that of the instrument on it, sinks. But if the sky be cloudy, or if a screen be placed over the thermometer, the cooling effect does not go on; because, though the earth is radiating as before, it receives rays from the clouds or screen, to compensate for the loss. When, then, the air is calm, and the heavens unobscured, cold is produced, and hoar-frost, or dew, is deposited, the earth cooling the air in contact with it, and thus depriving it of the power of holding the watery vapour in solution; the cold, therefore, invariably *precedes*, and is not, as was originally supposed, the consequence of the deposition.

Those bodies that radiate most powerfully, as grass, twigs, cotton, and woollen cloth, become coldest, and on them hoar-frost is deposited; while on resplendent surfaces, as there is little radiation, there is scarcely any deposition. Dr Wells has also shewn that the same objects, when of different colours, produce different effects on a thermometer placed on them. Thus, a piece of black cloth caused the temperature to fall much more than one of a light colour, the former giving forth most radiations. It is on this principle that we can explain,

why two thermometers, having different surfaces, will indicate different degrees of cold during night. If the one be resplendent, as when filled with mercury, it gives forth few radiations, so that its temperature is little reduced; but if the other be blackened, owing to its becoming a good radiator, it loses more heat than the other, and, as neither is receiving any, its temperature is more reduced. For the same reason, also, a differential thermometer, with a transparent and black ball, indicates cold in the stem of the latter, when exposed during a clear night, by the black one giving forth more caloric than the other.

The radiation of caloric during night, serves important purposes in the economy of nature. Were it not for the rays given forth from the earth, after sun-set, it would be heated to an intolerable pitch, by the constant absorption; whereas, by radiating at night, heat is abstracted, and the temperature is thus kept nearly uniform. In the vegetable creation, it is also of the utmost advantage. During dry weather, vegetation would cease from the want of water, but vegetables, from the nature of their surface, are well adapted for radiating heat; hence, in a clear and calm night, owing to the cold produced by the radiation, the moisture in the atmosphere is condensed, and deposited in the form of dew or hoar-frost, which not only supplies them with water, but also, by the disengagement of caloric during its formation, prevents the bad effects that would otherwise be occasioned by the radiation, so that the cold is the means of supplying them with water, and the formation of the water replaces the heat that was given out to produce it.

It is well known, that a very thin covering of snow on the ground, prevents in a great measure the bad effects of intense frost on vegetation, and it is commonly ascribed to its acting as a bad conductor, by which the earth is slowly deprived of its heat. This is not, however, the sole cause; indeed, with a thin layer this must operate to a very slight extent. It is to be explained on the principle, already illustrated, of its giving forth few emana-

tions, the snow being a bad radiator, losing little heat in this way.

The preceding remarks with regard to radiation, apply to the emanation from *warm* objects. Pictet, when performing experiments on this subject, discovered a very curious fact with respect to *cold* bodies. These, he found, when placed near the mirror, produced an opposite effect on a thermometer, and the reduction of temperature was in the ratio of that of the cold substance. This has been called *radiation of cold*, being at one time supposed that frigorific particles were actually given off to affect the thermometer. It is to be considered, however, merely as a case of radiation of heat, the thermometer now being the radiating body, and as it receives little or no caloric in return, its temperature sinks.

The effect of a cold body, in reducing the temperature of a thermometer, is shewn by placing a flask of ice at A, the ball of a differential being in the focus at K, (see cut, page 37.) In this case the fluid instantly begins to rise. If muriatic acid be poured into the flask, a greater degree of cold is produced, and the thermometer again begins to ascend.

We are indebted to Leslie, (Inquiry into the nature of Heat,) and Count Rumford, (Essays,) for our knowledge of the different facts concerning the effects of cold bodies. According to them, the radiations are regulated by the same laws as when warm objects are used, with regard to distance, difference of temperature between the cold substance and circumambient medium, and surface. Leslie found, that when the cubical jar used for the radiation of caloric was filled with ice, the cooling effect was least from the metallic side, greater from the glass, but much more so by the blackened one. This is also easily shewn by smoking the flask containing the mixture of ice and acid. The moment it is put near the mirror, the thermometer will be found to indicate a much greater degree of cold than before. The same was also the case with the reflecting surface; a bright metallic one reflecting most, while a glass or blackened

one reflected very little. Thus, if the gilded ball of a differential be put in the focus, the reduction of temperature is slight, whereas, when the blackened one is used, it is much greater, consequently, the radiating and reflecting powers are inversely to each other; those which are good radiators are bad reflectors, and bad radiators are good reflectors. The effect of screens between the thermometer and the cold body, is also precisely the same as with warm objects. All of these facts still farther prove, that we are to consider this as merely radiation of heat.

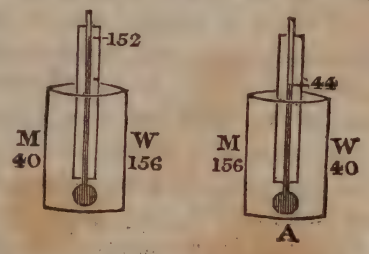
Leslie has shewn that the heating and cooling effect is the same, provided the bodies be at temperatures equidistant from that of the surrounding medium. Having filled a vessel with water at 140, when the atmosphere was 70, he placed a thermometer near it, by which it rose 10. He afterwards filled the same vessel with a mixture at 0, and the instrument sank 10. Rumford proved the same fact in another way. He filled two similar vessels, one with warm, the other with cold water, each at a temperature equidistant from that of the atmosphere, and on placing a thermometer in the centre between them, it was not in the slightest degree affected.

The radiation of cold, as it is commonly called, is most easily explained on the principle laid down by Prevost, that all objects, even though of the same temperature, are constantly radiating caloric, and consequently, when one sends forth more than it receives, its temperature sinks. When, then, the flask of snow is placed near one of the mirrors, both it and the thermometer in the focus of the other are throwing off radiations, but as the latter emits more than it acquires from the former, it indicates cold. On reducing still farther the temperature of the ice, it of course gives off fewer rays, so that the instrument now indicates a still greater cold; and the same also is occasioned by smoking the surface of the flask, by which, though it makes it a better radiator, it at the same time causes it to become a more powerful recipient of the calorific emanations; and as the rays are

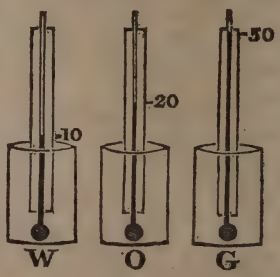
in greater quantity from the thermometer than from the flask, we can easily conceive why, by increasing the absorbing power of the latter, the temperature of the former should be more and more reduced.

Relative Quantity of Caloric in Bodies.

It has been already mentioned, that caloric has a tendency to pass from one body to another, till all become of the *same temperature;* we are not, however, to infer from this, that they contain the same quantity. Thus, if we take 10 pounds of water, and divide it into two parts, one containing 9, the other 1 pound, on applying a thermometer, they will be found of the same temperature; it is evident, however, that the caloric in them must be different; the one must have just nine times as much as the other. *Different quantities of the same matter, then, have different quantities of caloric. The same, we shall find, is the case with equal quantities of different bodies;* and that it is so, can be proved also by experiment, as by mixing them at different temperatures. If they produce by their union a *mean* temperature, we must infer that the caloric in each is the same; because that taken from the one, and transferred to the other, has lowered it as many degrees as it has raised the other; but this is very rarely the case,—the temperature is either above or below the mean. Thus, if equal weights of warm mercury and cold water be mixed in a jar A, they do not produce a mean heat; it is far below it. Suppose that the temperature of the mercury is 156, and of the water 40, that of the mixture is not the mean 98, it is only 44, so that the mercury has lost 112, but the water has gained only 4. Again, if equal weights of warm water and cold mercury be mixed, the resulting heat is above the mean. Suppose, as before, that the water is 156, the mercury 40, the temperature of the



mixture is not the mean 98, it is 152. In this instance, the water has lost only 4, but the mercury has gained on less than 112. In these experiments, then, the caloric which has raised or depressed the temperature of the mercury 112 degrees, has affected that of the water only 4, or 1-28th part. Hence, the latter requires 28 times as much as the former, to bring it to the same height; and if so, it must contain 28 times as much. That the caloric in bodies is different, is proved aslo by adding equal quantities to the same weights of them; and for this purpose, we have merely to use always the same measure of boiling water, provided this does not act chemically on the substance to which it is to be added. On the addition of a measure of warm water to the jar W, containing a pound of water at 50, the temperature will rise, say 10 degrees. On adding a similar measure to O, having a pound of sperm oil, it will rise 20; and the same addition to G, in which there is a pound of powdered glass, will cause a rise of 50. Here, then, equal quantities of caloric added to water, oil, and glass, have raised the temperature of the first 10, of the second 20, and of the third 50 degrees. If we wished to raise them all the same number, say 50, it is evident that we must add twice and a half as much to the oil, and five times as much to the water as to the glass. If so, oil must contain twice and a half as much, and water five times as much, as glass; the quantities of caloric in them are, therefore, as glass 10, oil 25, water 50; or, taking water as the standard, and calling it 1000, they are water 1000, oil 500, glass 200. The same is the case with all other substances, the caloric necessary to raise their temperature to the same height, varying in almost every different instance; hence they are said to have different *capacities* for it, (Black's Lectures.) By the term capacity for caloric, then, is meant, the power which bodies have of receiving it, by which their temperature is to be affected, some more than others.



The caloric thus retained, has been called specific caloric. It is necessary that we be particular, in drawing the distinction between these terms. By capacity is meant, the power which bodies have of receiving caloric,—by specific caloric is understood, that retained by the capacity. Temperature, on the other hand, denotes the effect produced on a thermometer, by the heat, retained by the capacity.

Different methods have been recommended, for ascertaining the capacity of bodies for caloric. Perhaps, the best is that already mentioned, mixing them at different temperatures, and ascertaining the heat of the mixture; provided there is no chemical action between them. Thus, suppose a pound of water at 100, be mixed with a pound of oil at 40, the resulting heat will be 80, that is, the water will lose 20, but the oil will gain 40; again, if a pound of oil at 100, be mixed with a pound of water at 40, the heat of the mixture will be 60. Here the oil has lost 40, but the water has gained only 20. In both of these experiments, then, a quantity of heat, which has affected the temperature of the water 20, has affected that of the oil 40; so that if it is wished to raise, or reduce both 40, twice as much caloric must be taken from or added to the water, as to the oil; it is said therefore to have double the capacity, of course twice the specific caloric, that the oil has.

When the substance, the specific heat of which we wish to find, acts with water, some other body, as powdered glass, must be used. Its capacity compared to it may be found, and from it, it may be referred to water. It is necessary, in performing these experiments, that due attention be paid to the vessels, to have them as much alike as possible, and the different circumstances which influence the heating and cooling of bodies must also be attended to.

Other methods have been practised, for finding capacity. That followed by Wilcke, is on the same principle as the one described. He brought the body, sup-

pose a piece of iron, to the heat of boiling water, by suspending it in it for some time. It was next put into a vessel containing its own weight of water, at 32, and when the equilibrium was established, the temperature was taken. The capacity was inferred, by knowing the number of degrees lost by the one, and gained by the other; it being inversely as the effect on each.

Lavoisier and Laplace, in their experiments, employed the calorimeter, (see page 21.) To find the capacity of a solid, it was put into the inner cage; fluids were put into a flask, and suspended in the cage. According to the ice melted, they inferred the capacity, which they supposed to be just as the quantity of water obtained. Thus, if a pound of water, in cooling from 212 to 32, liquefied a certain quantity of ice, and the same weight of oil, at a similar temperature, only half the quantity, then the capacity, or the specific heat of the latter, is only half of that of the former. This method is apparently free from objection, but it has been already mentioned, that we cannot place any confidence in the instrument, the whole of the water formed not being procured.

The preceding experiments apply to solids and fluids only. The methods of ascertaining the capacity of gases, are far from being accurate, and there are great difficulties attending the performance of them.

It will be afterwards shewn, that when gases are suddenly rarefied, their capacity is increased; and when, on the contrary, they are condensed, it is diminished, so that heat is taken in, in the former, and given out in the latter instance. Mr Leslie has availed himself of this, in trying the capacity of gases. For this purpose, having placed a delicate thermometer in the receiver of an air pump, part of the air is withdrawn, by which the temperature falls, but time is given for it to come to what it was before. When this has happened, the stop-cock is opened, and air allowed to rush in, by which that in the receiver is condensed, heat is given out, and the thermometer rises. To ascertain the capacity of gases, by

attaching bladders with them to the stop-cock, they are allowed to rush in to the partially exhausted receiver, by which the air in it is condensed, and the same quantity of caloric, it is supposed, will be disengaged; but as the gases themselves may take in different quantities, the effect on the thermometer will be different; that which requires the most, will have its temperature, and consequently that of the thermometer, least elevated. The capacity is therefore inferred to be inversely as the rise of temperature.

Thus, suppose, when air is admitted, the rise is 10, on the introduction of another gas B, it is 20, and of a third, C, 40; then the capacity of air being considered 1000, that of B is 500, and of C 250, because a- .ne same heat added to these, has affected their temperatures, as 10, 20, and 40, if we wished to raise them all the same numbers, we should require to add only half as much to B, and a fourth as much to C, as to air. B would therefore contain half as much, and C a fourth as much, in other words, have half, and a fourth, of the capacity of air. The principle of this method is the same as that already mentioned, of adding equal quantities of heat to bodies, as in the experiment with water, oil, and lead. The results, however, do not always agree, which would lead us to suppose that there is some source of error, of which we are not aware.

Lavoisier and Laplace, in finding the capacity of gases, caused them to pass through spiral tubes fixed in the middle vessel of a calorimeter, and having a thermometer at each end of the tube, to ascertain the temperature of the gas, as it entered and came out. According to the ice melted, so is their capacity.

By these different methods, the capacity of different bodies, and of course their specific caloric, has been ascertained. It must not however be supposed, that when the term, specific caloric, is used, it is meant to denote the *actual quantity* in a body. Experiments go no farther than to find the quantity in one, *compared with that in another*. It is necessary, therefore, to have some sub-

stance as a standard, and to which all others can be referred. And for this purpose, water has been fixed on for solids and fluids, and air for gases, and called 1000. If, then, the capacity of any solid or fluid be 2000, it means that, weight for weight, it will require twice as much to raise its temperature to the same height as water does.—*For the capacities of different bodies, see Appendix.*

In referring to that table, the numbers must be considered as pointing out the relative quantities of caloric, and, of course, the effect that equal additions would produce. Thus, the capacity of water being 1000, that of mercury is 28, by which we are informed, that at any temperature, the caloric in water being taken as 1000, that in mercury at the same is only 28. Hence, we are also informed, that if equal quantities were added to them, the rise would be inversely as 1000 to 28, that is, 1 to 36; consequently, if we wish to raise them to the same degree, we must add 36 times as much to the water as to the mercury, and hence the principal practical application of a knowledge of the capacity of different bodies.

By the methods already described, the capacity of bodies has been ascertained, of course at the temperatures at which the experiments have been performed. Are we, however, from this to infer, that it is the same at any other temperature? It is well known that the capacity of a body in the solid and fluid form is different, but will equal additions of caloric raise its temperature, when in the same state, an equal number of degrees at any part of the thermometric scale? Though some have supposed that this is the case, yet there are strong arguments in favour of an opposite opinion. It is well known, that when by any means we condense a body, its capacity is diminished, and on the contrary, when it is enlarged, it is increased. From this, then, we ought to infer, that at high temperatures, at which a body is in a state of great expansion, the capacity is much greater than when by the loss of caloric it has been contracted. The experiments of Dulong and Petit (Ann.

of Phil. xii.) support this opinion. They found the specific heat of a substance to increase with the temperature. Thus, that of iron, between

32 and 212	is 1098
32 and 392	1150
32 and 572	1218
32 and 658	1255

The same, they found, was the case with mercury, zinc, antimony, silver, copper, and glass. That of platinum did not vary in the range of temperature, at which the experiments were performed ; from 32 to 572.

From what has now been said, it is evident that temperature may be changed in two ways ; either by the addition or abstraction of caloric, or by the alteration of capacity. Thus, if by any means the capacity of a body is enlarged, it requires less caloric than before, to keep it at the same degree; part must therefore be disengaged, but the moment that this is set free, it raises the temperature. On the contrary, when by any means the capacity is increased, it requires more heat; if this be not supplied, it must take it from itself, and hence its temperature sinks.

Many curious and important phenomena are explained by the doctrine of capacity. Irvine has endeavoured by it to account for the generation of heat and cold during chemical actions ; and Crawford has applied it to the explanation of that power, by which animals are enabled to keep their temperature above that of the surrounding medium. It will be afterwards shewn, that during liquefaction and evaporation, cold is produced, and this is also supposed to be owing to a change of capacity, which ensues on the alteration of form that the bodies experience, *(see Liquefaction, Evaporation, &c.)*

Liquefaction.

It has been already proved, that as a body receives heat, it is enlarged. In continuing its application, it continues to expand till it arrives at a certain tempera-

ture, when a change of a different nature ensues. It now becomes liquid, and it is said to be *melted, liquefied,* or *fused,* and the change is called *fusion* or *liquefaction,* which is the second general effect of caloric. On the contrary, when heat is withdrawn from a fluid, it contracts, and continues to do so, till at a certain temperature it becomes solid, and it is then said to be *frozen* or *congealed.* In this way almost every solid may be made fluid, and almost every fluid solid; hence, as all fluids at a natural temperature contain heat, and as by abstracting it we can make them congeal, we infer that the solid is the natural form of these bodies. Those which cannot be liquefied are such as are decomposed before they arrive at their melting point. Thus coal, when heated, is decomposed, and new products are formed by its elements entering into a different state of combination, before it arrives at the temperature necessary for its fusion. On the contrary, alcohol and a few other fluids have not yet been congealed, as is also the case with some gases; these, however, it is inferred, would become solid, were a sufficient quantity of caloric withdrawn from them. So that *the solid must be considered as the natural form of all bodies.*

The change from solid to fluid, occurs at a certain temperature in each; thus, ice melts at 32, sulphur at 218; every other substance has its point of liquefaction fixed. Some by the addition of caloric liquefy, without going through any gradation from hardness to fluidity, as is the case with ice, while others, as tallow and wax, pass through different degrees of consistence, before they become fluid.

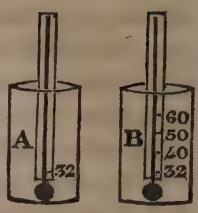
Though the point of liquefaction is determinate, yet by uniting substances of different fusibility, the temperature at which they become fluid may be varied, and many, which cannot in the usual way be made fluid, may be fused by particular contrivances, as has been proved by the experiments of Sir J. Hall, (Ed. Ph. Tr.) Lime-stone, which is a compound of lime and carbonic acid, cannot be fused by heat, because, before it

arrives at the temperature necessary for its fusion, it is decomposed, and one of its ingredients is given off in gas; but if it be subjected to heat and pressure at the same time, so as to prevent the escape of the gaseous ingredient, liquefaction ensues. The same is the case with many other substances.

It has been found also, that though bodies become fluid at a fixed temperature, this may be made to vary. Thus, if pure water is exposed in an open vessel, to a cool but calm atmosphere, so that it be kept without agitation, it may be cooled many degrees below the freezing point without becoming solid; indeed, in some instances, it has been reduced to 5 without freezing. If, however, the vessel be struck so as to agitate the water, the whole of it becomes solid, and the temperature rises to 32. The same occurs with many other fluids, as saline solutions, which, without undergoing any change, often allow their temperature to fall far below that at which congelation should take place.

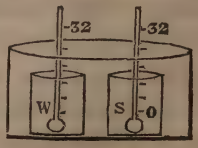
Though a substance can be liquefied by the application of heat, yet, when it is brought to its melting point, the whole of it does not suddenly become fluid. On the contrary, the liquefaction goes on gradually. Thus, if heat be applied to a flask with tallow, it begins to melt, but it requires the continuance of it for some time, till the whole of it is liquefied. This shews that it is not merely necessary to bring a body to its melting point, there must be an absorption of caloric, otherwise there is no liquefaction. But besides this, though heat is absorbed, there is no elevation of temperature. We are indebted to Dr Black for the discovery of these important facts, not only that heat is absorbed, but that, during the absorption, the temperature does not rise. (Black's Lectures.) This remarkable circumstance is proved by a very simple experiment; we have merely to add heat to any body, so as to cause it to liquefy, and during the change, mark the effect on the thermometer; but the result is still more striking, if we use the same substance in different forms. For this purpose put into a jar, A,

some ice, and into another, B, some ice-cold water, and in each let there be a thermometer. By adding to these equal quantities of caloric, the results will be very different. To get similar quantities of caloric, we have only to take equal measures of a substance at the same temperature, as boiling water, which is always, under certain circumstances, at the same heat. If a measure of boiling water be added to the water in the jar B, the temperature is affected, as is shewn by the rise of the fluid in the thermometer, say to 40. On adding the same measure to the ice A, part of the latter is melted, but there is not the slightest rise of temperature; the thermometer still continues at 32. The addition of another measure to the water causes a greater elevation, say to 50, but, on adding it to the ice, more of it is melted, but the thermometer still stands at 32. In this instance, then, the heat has been absorbed by the ice, but the temperature is not elevated; indeed, it is necessary to continue the addition, till the whole of it is melted. If, after this, we still throw it in, the temperature begins to be affected.



As in this experiment caloric is absorbed by the ice, yet the temperature not raised, Dr Black said that it becomes *latent*, and hence it has been called *latent heat*, to distinguish it from that which affects the temperature, and which has been termed *sensible heat*.

The reverse of this may be expected,—that when a substance passes from fluid to solid, it should give forth caloric, without having its temperature lowered; and that it is so, has been proved satisfactorily with water. If two vessels, one with ice-cold spirit of wine, S, another with ice-cold water, W, and each having a thermometer in it, be placed into a freezing mixture of salt and snow, caloric will be taken from both; by which the latter will be frozen, but the former will continue fluid.



The thermometer in the spirit will sink, say to 0; but that in the water will still remain at 32. Here, then, heat has been withdrawn from the spirit, so as to bring it down to 0; it must also have been taken from the water, yet its temperature is not diminished. And why? because the water being brought down to its freezing point, begins to congeal, and, during its congelation, must give forth heat. Thus, then, it is proved, that a substance, in passing from fluid to solid, gives out a large quantity of caloric, but the loss of which does not in the least diminish its temperature; in other words, its *latent* heat is disengaged.

Dr Black was not content with having proved the general law of the absorption and evolution of caloric, during the changes of form mentioned; he endeavoured to find the actual quantity, or rather the actual number of degrees. For this purpose he exposed in a room, the temperature of which was 47, two similar flasks, one with ice at 32, the other with the same weight of water at 33. In half an hour the latter had risen to 40, but the ice, though part was melted, still continued at 32, and required 10½ hours for liquefaction, at the expiry of which the water formed was also raised to 40. Dr Black here estimated the quantity that entered the ice, by comparing with it that which the water had acquired during the first half hour, and which was 7 degrees. This, multiplied by 21, the number of half hours the ice took in liquefying, gives 147, but from this there must be deducted 8, or that which had raised the temperature from 32 to 40, leaving 139; so that as much caloric must have entered the ice during its liquefaction, as would have raised a *similar quantity of water* 139 degrees.

He proved also, by a different set of experiments, that the same was given out during congelation. He put 59½ drachms of ice at 32, into 67½ of water at 190, by which the whole of the former was liquefied, and the resulting temperature was 53, which was of course also that of the vessel in which the experiment was made, and which he calculated was equivalent to 4 drachms of

water. Here, then, 67½ of water, and the vessel equal to 4, in all 71½, lost 137 degrees, which was transferred to the ice, and considering its proportion to the water, ought to have raised it 86, but it rose only from 32 to 53, or 21; so that 65 had disappeared. Now, from the difference between the capacity of ice and water, and considering also the difference in their weight in this experiment, these ought to have raised the latter 143, and which had entered the ice during liquefaction; so that the result of this agrees very nearly with the former. He found also, that by adding a certain quantity of ice at 32, to water at 176, the whole was liquefied, and the temperature of the fluid was 32; in other words, it had lost 144 degrees, which must have been absorbed by the ice. From these and other experiments, Dr Black came to the conclusion, that as much caloric enters ice, during its liquefaction, as would elevate the temperature of the same quantity of water about 140 degrees; and that this is again given forth when the water is congealed.

The experiments of other Chemists have given results different from this, but the difference is so trifling, that that of Black is generally considered correct, more particularly as it is the mean of the others.

It must be kept in mind, that the caloric which enters ice during its liquefaction, is said to be as much as would affect the temperature of an equal quantity of *water* 140. From the difference of capacity between ice and water, the same would raise the former 155, their capacities being, according to Irvine, as 9 to 10.

It has been proved, that what was established by Dr Black, with regard to water, holds true with other bodies. Dr Irvine found that spermaceti, during liquefaction, absorbed as much caloric as would raise the temperature of the fluid 145, and that tin took in as much as, if added to the solid, would affect it 500. Others have made experiments on the subject, which show, that all substances in passing from solid to liquid, absorb caloric, which does not raise their temperature,

and that, in passing from liquid to solid, they give it out, without having their temperature diminished.

Different opinions have been entertained with respect to the cause of this absorption and evolution of heat. Dr Black imagined, that when a body arrived at its melting point, it absorbed caloric, by which it was made to assume the fluid form; the absorption thus being supposed to be the *cause of* the fluidity, and hence has originated the idea, that caloric exists in two conditions, in a free state, or uncombined, and affecting the temperature, and in a state of combination, by which it has laid aside its ordinary properties, and is therefore said to have become latent. Dr Irvine, however, did not allow that any of it becomes latent. He supposed, that a solid, during its conversion to fluid, suffers an increase of capacity, it must therefore require more heat than before to keep it at the same temperature, consequently it absorbs it, and as the heat taken in goes to satisfy this increased capacity, it cannot of course have any effect on the thermometer. If this opinion be correct, the absorption is not the *cause*, but the effect of the liquefaction. Again, on withdrawing caloric from a fluid, it is brought to its point of congelation, and, still continuing to remove it, it becomes solid; the abstraction, according to Black, *causing* the congelation; whereas, according to Irvine, the moment a substance is brought to its congealing point, it becomes solid, its capacity is diminished, it requires less heat than before, part of it must therefore be disengaged, so that the evolution is not the cause, but the *consequence* of the change of form.

By this absorption and evolution of caloric, many important phenomena of nature, and the changes induced during chemical action, may be accounted for. When heat is applied to any substance, tallow, for instance, it is very slowly melted; and though we continue the heat for a considerable time, there may some of it still remain solid. This is explained by the absorption of caloric, a large quantity of which must be added, before the whole can be liquefied. Hence also the cause of the time requir-

ed to melt immense masses of ice, or collections of snow. It is not merely necessary, that the state of the weather be such as to raise their temperature to the melting point; a great deal of caloric must be thrown in, otherwise they will not become fluid. Were it not for this, dreadful deluges would follow the liquefaction; but as the heat is slowly absorbed, they are gradually melted, and the water formed is thus distributed over the surface of the globe. The reverse of this is equally beneficial; for did this law not exist, the moment that the water of a lake is cooled to its freezing point, the whole would congeal, and prove destructive to the life of its inhabitants: Whereas, owing to the necessary extrication of caloric, the freezing goes on slowly; besides, heat is thus given out, which, in no small degree, lessens the intensity of the cold that would otherwise ensue.

We are thus also enabled to account for the production of cold, by what are called freezing mixtures. When a solid and a fluid, or two solids, act on each other, by which they become fluid, heat must be absorbed, to enable them to put on this form; they therefore take it from any body brought in contact with them. Ice and salt, for instance, when mixed, become fluid, and produce cold, both of them, during their liquefaction, absorbing heat.

Dr Black and his followers suppose that in this case the substances absorb caloric, and become fluid; whereas, according to Irvine, they first become fluid, suffer an increase of capacity, and then absorb heat.

Dr Black and others have shewn, that by certain means a fluid may be cooled below the freezing point without congealing, but that, if by any means we cause it to assume the solid form, it instantly rises to the point of congelation, as is well illustrated in the solution of some of the salts in water. If, for instance, a flask with nearly a saturated solution of glauber salt at a boiling heat, be surrounded by saw-dust, and kept there without the slightest agitation, its temperature will fall

to that of the surrounding atmosphere, but without depositing any crystals. If, however, the vessel after this be shaken, or if a small piece of the salt be thrown in, crystallization instantly commences, and the temperature rises. Now, in this instance, the moment that the change of form commences, heat is disengaged, and it is in this way that the rise of temperature is to be accounted for, the latent caloric becoming sensible, and affecting the thermometer.

Advantage has been taken of this change in the quantity of caloric, to determine whether it is possessed of weight. In the experiments made on bodies at a natural temperature and at a red heat, owing to the currents induced in the air by the caloric communicated to it by the warm body, the arm of the balance was made to move, and hence originated the difference in opinion with respect to it, some asserting that it had no weight, while others concluded that it was actually possessed of levity, consequently, when added to a body, it made it become lighter. Thus, if a ball of clay at a natural temperature be weighed, after bringing it to a red heat, it appears to be no longer equipoised, because the currents of warm air passing up from it make the arm of the beam ascend. Rumford luckily thought of settling the dispute, by taking objects in their different forms, by which he had equal quantities of matter at the *same temperature*, but containing very different quantities of caloric. He took similar flasks, containing equal weights of water, alcohol, and mercury at 50. He attached the water and the mercury to the opposite ends of a beam, which was so delicate that it was affected by a change in weight, amounting to not more than the millionth part of that with which it was loaded. Having placed them in a room, the temperature of which was 30, the water was frozen in 48 hours; the mercury of course still continued fluid, but there was no difference in their weight. The same was afterwards done with the water after being again melted, and the alcohol; and though the former was again frozen, they still continued equipoised. Here, then,

the water, owing to its greater capacity, for its capacity to that of mercury is 28 to 1, must, during the reduction of temperature, and also during congelation, have given forth a much greater quantity of caloric than the others, yet there was no sensible difference in the weight. Rumford, therefore, concluded, that if caloric is possessed of gravity, all attempts to discover it must be fruitless, as it is not sufficient to affect our most delicate instruments

Evaporation.

By applying heat to a fluid it expands, and continues doing so till it arrives at a certain temperature, when it undergoes another change; the cohesion among its particles is so far overcome, that it passes into the state of vapour; and the process is called *Evaporation*, which is the third general effect of caloric. The conversion of a fluid into vapour is well illustrated in the familiar instance of boiling water, which, when heated to a certain point, is converted into vapour, or steam. The agitation, called boiling, is owing to the vapour generated below, rising through the water above it. If the heat be continued long enough, the whole of the fluid is evaporated.

This process must be distinguished from the evaporation of a fluid, when exposed in an open vessel at a natural temperature. Thus, if water be kept exposed to the air, it slowly disappears, which is supposed to be owing to an attraction existing between the air and the fluid, by which it is held in solution in the state of vapour. This is called *spontaneous evaporation*, and will be considered when treating of water.

When we withdraw heat from vapours, they are condensed, or again become fluid. It is well known, that if a cold object, as a plate of metal, be held near the mouth of a tea-kettle in which water is boiling, it is instantly covered with moisture, owing to the condensation of the steam. That a vapour is condensed as its temperature

falls, may be proved in another way, and still more satisfactorily; but, before stating the experiment, it must be premised, that the air of the atmosphere, though a light fluid, yet, from its great bulk, presses on the surface of the earth, and of course on all other objects, with a weight of 15 lb. on the square inch; and which pressure is equal to that of a column of mercury of 30 inches, or of water of about 32 feet; so that in any exhausted vessel these would rise to the height stated. To prove that vapour is condensed as its temperature falls, put a little water into a flask, and boil it for some time, by which the whole of the air is expelled, and that part not occupied by the fluid, is filled with steam. When it is in this state, cork it tightly and cool it, then plunge the mouth of it into a basin of water, and remove the cork, and the moment that this is done, the fluid will rush up, being forced in by the pressure of the atmosphere, proving that there must have been a vacuum occasioned *by the condensation of the vapour.*

The condensation of vapour is proved also in another way, and perhaps still more satisfactorily, as the condensed substance may be actually collected: all that is necessary is, to put water into a retort A, to which a receiver B is adapted, and which must be kept cool, as is easily done by putting it into a plate D, and surrounding it by a mixture of ice and water; or it may be covered with a piece of cloth, and a stream of water allowed to flow on it, either by means of a syphon, or, which is more easily managed, by a funnel C, the throat of which has a grooved cork in it, and by which we can allow a large or a small stream to flow as we please. By the application of heat to the retort, the water is



dissipated in vapour, and which is again condensed in the cool receiver.

The part of the thermometric scale at which bodies assume the vaporific state, varies in almost every different instance.—Some evaporate at a low temperature, while others require a most intense heat; indeed many have not yet been converted into vapour. The former have been called *volatile*, the latter *fixed;* terms, however, which are very indefinite. Other bodies, on the contrary, are at a natural temperature in the aeriform state, and many of them cannot, by the application of an extreme degree of cold, be made to lay aside this form. This has given rise to the division into *vapours*, or those which are easily condensed, and *gases*, (a term derived from the German word *gas*, signifying air), or *permanently elastic fluids*, which, as the name would lead us to suppose, cannot be condensed. Thus, if heat be applied to chalk, a substance is given off in the aeriform state, and though the temperature of this is reduced, as by collecting it in a jar over a water trough, it still remains in the same form. This division is, however, incorrect. It is now well known, that what were at one time supposed to be permanently elastic, can be condensed either by the application of cold, or of strong pressure, as has been beautifully illustrated by the experiments of Faraday, (Ph. Tr. 1823), in which, by a very simple contrivance, merely by subjecting the gas to a pressure produced by itself during its formation, he has succeeded in causing many of them to become fluid. Again, by making gases enter into union either with themselves or with other bodies, they lay aside their gaseous form, so that we must consider them merely solids converted into the aeriform state, by having combined with a sufficient quantity of caloric at a very low temperature, and which caloric we cannot in all cases withdraw.

The preceding remarks apply in a great measure to the conversion of a fluid to vapour, and of a vapour to fluid; there are many instances, however, of a solid

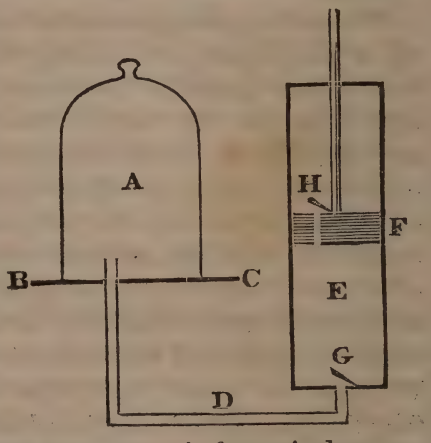
changing at once to vapour, and a vapour to solid, without being previously fluid. Thus, on applying heat to iodine, it does not liquefy, it at once passes off in vapour of a beautiful violet colour, which, as it reaches the cool part of the apparatus, is condensed in slender crystals.

The distinguishing feature of aeriform bodies is elasticity, or the property of resuming their former bulk, after having been condensed by pressure, and the pressure is again removed. By that of a few inches of mercury, air and other elastic fluids are much diminished, and by compression alone many of the gases have been condensed; but the moment the compressing force is withdrawn, they again become gas. *Rarity is another feature of vapours*, and which is so great as to cause them to be invisible, unless when they are of a particular colour. Thus, a vessel filled with steam is perfectly transparent. We may have some idea of the rarity of these bodies from the space a fluid occupies when converted to vapour; steam, for instance, is between 1700 and 1800 times the volume of the water from which it is formed.

Though bodies pass off in vapour at different temperatures, yet, cæteris paribus, *the vaporific point of a fluid is always the same.* Thus, water boils at 212, mercury at 656. There is one circumstance, however, that materially affects the boiling point, which is the pressure. As it is increased, it becomes higher, but when diminished, it is lowered. That the boiling point is lowered as the pressure is diminished, may be proved in different ways. By means of an air-pump, we are enabled to withdraw the air from a bell-glass, so that any substance placed under it must have less pressure than when exposed to the atmosphere.

Before stating the experiment, it is necessary to explain how the air-pump acts. This will be most easily understood by attending to the figure, which represents a vertical section of a pump, in its simplest form. A is the bell-glass, or *receiver*, that is to be emptied of its air, placed on the plate of the pump, B C. This commu-

nicates by means of a tube D, with the syringe E, in which there is the piston F, that moves upwards and downwards, but quite air-tight. At G, the opening of the pipe D, there is a valve which allows air to flow from the receiver into the syringe, but prevents its return. In the piston there is a tube with a valve at H, which allows air to pass from the under to the upper part of the syringe, but prevents it from going down again. The construction of this valve is very simple; it is merely a small piece of oiled silk, tied loosely over the mouth of the tube. When the air passes through, it raises it; but on again attempting to return, it forces it down on the tube, which thus prevents it from passing. When we wish, then, to exhaust the receiver A, by raising the piston F, the air, owing to its elasticity, expands, and is thus divided between it and the syringe, the valve in the piston being shut when it was raised, by the pressure of the air above it, which is thus kept from passing through it into the lower part of the cylinder. On again forcing the piston down, the valve at G is shut, while that at H is opened; the air therefore below, being prevented from returning into the receiver, escapes at H. When the piston is raised, the valve at H is shut, and that at G is opened, the air in the receiver is therefore again divided between it and the syringe, and on again forcing the piston down, the air drawn from the receiver is expelled at H. In this way, by alternately raising and depressing the piston, the greater part of the air may be removed. It is evident, however, that we cannot take out the whole; for when the elasticity of that left becomes very slight, it ceases to move the



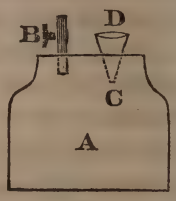
valve, so that any farther working of the pump does not draw out more.

If a substance be placed in the receiver, and the air be withdrawn, it must sustain less pressure than when exposed to the atmosphere. To prove, then, that the boiling point of a fluid is lowered as the pressure is diminished, if a jar with a mixture of equal measures of cold and boiling water be placed under the receiver, and the air withdrawn, it begins to boil, and will continue to do so for some time, even though the temperature be perhaps 140 degrees below the usual boiling point.

That the boiling point of a fluid is lowered as the pressure is diminished, is proved also in another way. If water be boiled in a flask for some time, the whole of the air of the vessel is expelled, and the upper part of it is filled with steam. If, in this state, it be corked tightly, and plunged instantly into cold water, it boils briskly, and continues to do so for some time; but if it be plunged into boiling water, the ebullition ceases. On again putting it into the cold water, it begins to boil, and on again placing it in the warm fluid, it ceases to do so. In this instance, when the vessel is corked, and putinto the cold fluid, the vapour in the upper part is condensed; there is thus produced a vacuum; and as the fluid within is relieved of its pressure, it boils, even though it is below its boiling point. On putting it into warm water, the vapour is prevented from being condensed; it exerts, therefore, a pressure on the fluid nearly the same as that of air; and as the temperature is below the point of ebullition, it does not boil. Here, then, by keeping the flask in cold water, the fluid, by the condensation of the vapour, is kept under a diminished pressure, by which the boiling point is lowered. In this way it may be reduced many degrees; indeed, did no pressure exist on fluids, there would not be any body in that state; it would instantly assume the form of vapour.

If, instead of diminishing, we increase the pressure, the boiling point becomes higher. Thus, if heat be applied to water in a close vessel, it may be raised many degrees

beyond 212 without boiling, the vapour at first formed exerting an additional pressure on the fluid, and thus preventing its ebullition. The apparatus by which this is most easily shewn, is that called *Papin's Digester*. It is a strong metallic vessel A, with a lid, secured to it by luting. In the lid there is a stop-cock B, and there is also another opening C, shut by a stopper D, loaded with a certain weight, to prevent the too great accumulation of steam; for when it is collected in great quantity, the weight is raised, and the superfluous vapour allowed to escape. When water is heated in this apparatus, it may be raised many degrees beyond the boiling point; but after removing it from the fire, the moment the stop-cock is opened, so as to relieve it of its additional pressure given by the steam, it begins to boil, and continues to do so for some time, shewing that its temperature must have been far beyond its usual boiling point, the caloric that keeps up the ebullition, being that which had raised the fluid above this. It has been ascertained by experiment, that water may in this way be brought up to 400, or even 500; indeed, were the vessel of sufficient strength, it might be made much higher.



As the pressure which fluids sustain from the air is greater at one time than another, the boiling point varies. In this country, the range of the barometer, the instrument used for ascertaining the pressure of the atmosphere, is about 3 inches, from 28 to 31, and it has been ascertained, that for each inch of difference, the boiling point of water is altered $1\frac{1}{2}$ degree of the thermometer; it may therefore vary nearly 5. It has been already mentioned, that in the construction of a thermometer, *(See page* 15,) one of the fixed points of the scale is found by plunging it into boiling water. It was, however, stated, that there was one circumstance to be attended to, the pressure of the atmosphere. In graduating thermometers, therefore, we must attend to the height of the barometer. We must either seize the op-

portunity when it is at its average height, 30, at which water boils, at 212, or we must make allowance for the difference, about $1\frac{1}{2}$ degree for each inch it is above or below it.

The following table shews the difference in the boiling point, by a difference in atmospheric pressure, and, of course, enables us to mark the degree on the stem of a thermometer, when the ball is in water boiling at these pressures.

Barometer.	Boiling point.	Barometer.	Boiling point.
31.	213.76	29.	210.19
30.5	212.88	28.5	209.31
30.	212.	28.	208.43
29.5	211.07	27.5	207.55

If therefore the barometer should be at 31, the part of the stem must be marked $213\frac{3}{4}$.

It is evident also from the preceding remarks, that water must boil at different temperatures at different heights, even though there is no change in the state of the atmosphere, the pressure being less as we ascend; and, as we know the variation which the difference in pressure occasions, it affords us an easy method of finding the height of an object. It has been ascertained, that for each degree that the boiling point is lowered, we must allow an ascent of about 530 feet. We have, therefore, merely to find the temperatures at which water boils at the top and bottom of the object, and allow 530 feet for each degree, taking care, at the same time, that there has been no change in the state of the atmosphere, which would cause a difference in the boiling point, independent of that occasioned by the diminution of pressure owing to the difference in height. This method of ascertaining the height of an object, has been brought to a great state of perfection since the invention of a thermometer by Mr Wollaston, (Phil. Tr. 1817,) each degree on the scale of which can be divided into 1000 parts, so that each division in the difference of the boiling point is

equal to a variation in pressure occasioned by 6.36 inches fo height. By this contrivance, he has been enabled to ascertain the height of a common table.

Another circumstance affecting the vaporific point, is the nature of the vessel. Gay Lussac has shewn (An. of Phil. xii.) that in those of glass it varies considerably, being sometimes 214. He found, however, that on throwing in a coil of wire, some sand, or powdered glass, the boiling point was lowered, and the ebullition went on more steadily. This seems to be occasioned by the asperities of the glass, and the points presented by the sand or wire from which the vapour arises; for it is well known, that in cases of effervescence, the gas generally proceeds from some point of a solid in the fluid. Hence, also, the use of throwing into boilers some pieces of metal, or indeed any object by which the evaporation is greatly promoted.

Bostock has shewn that the boiling point of other fluids may be altered in a similar way. Thus, by throwing some chips of cider-wood into ether, it boiled at 50, and into alcohol, at about 30, below their usual points of ebullition, (An. of Ph. *N. S.* ix.)

It has been already mentioned, that by increasing the pressure, the boiling point becomes higher. *If the fluid is prevented from boiling by confining the vapour, the elasticity is increased to a great degree;* and that it is so is proved by a very familiar experiment, in applying heat to a candle cracker. This is merely a small glass ball containing water. By putting it in the flame of a candle, the water is made to boil, and in the course of a very short time causes an explosion, owing to the expansive force of the steam, for on the continuance of the heat it accumulates, and the elasticity becomes so great as to burst the globe. The dreadful accidents occasioned by the falling of a drop of water on melted metal, are accounted for in the same way, the amazing force exerted by the steam suddenly generated by the heat, throwing about the melted metal. The explosions of the boilers of steam engines are owing also to the same

cause; the valve for allowing the escape of the superfluous vapour becoming fixed, it is prevented from escaping, and thus accumulating, its elasticity becomes so great as to burst the vessel. *It must be kept in mind, however, that in augmenting the elasticity of vapour by an elevation of temperature, it must not be separated from the parent fluid.* If removed from this, by increasing the heat, the elasticity is increased only in a small degree, but keeping it in contact with the fluid from which it was formed, every addition of caloric causes the formation of more and more vapour, so that the elastic force becomes very great.

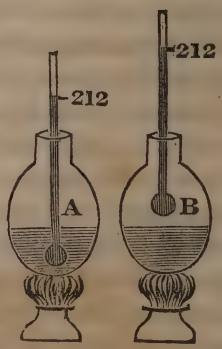
Mr Dalton has endeavoured to ascertain the elasticity of the vapour of water at different temperatures, while it is in contact with the parent fluid. From his experiments he has concluded, that the elastic force of steam generated between 32 and 212, increased by a gradually diminishing geometric progression, as the temperature was elevated; from which he has given a table of the elasticity at different temperatures. The table given by Ure (Phil. Tr. 1818,) agrees very nearly with that of Dalton, as far as 212, but above this there is a considerable difference, owing to a difference in opinion entertained, with respect to the ratio by which the elastic force is increased, *(see Appendix.)*

The elasticity of the vapours of different bodies is different when at the same temperature; but Dalton has established the general law with respect to them all, that it is the same when they are generated at the boiling point, and that at equal distances above or below this, it is also similar. Thus, that of steam at 212, is equal to 30 inches of mercury, that of ether at 102, its boiling point, is the same. Farther, the elasticity of the vapour of water at any number of degrees below the point of ebullition, say 40, is just the same as that of ether at 40 below its boiling point.

Though by confining the vapour the elasticity becomes very great, and of course prevents the fluid from boiling, yet, provided the vessel is of sufficient strength,

there is a certain point at which the whole of it evaporates. De la Tour has shewn (An. de Chimie, v. xxi.) that alcohol heated to 405 in a strong close tube passed into vapour, which had a pressure of 119 atmospheres. The same was the case with ether at 320, the elastic force being 37 atmospheres.

It has been already proved, that a solid, when becoming fluid, absorbs caloric, without having its temperature elevated; the same occurs when a fluid is changed to vapour. When water, for instance, arrives at a boiling point, the whole of it does not in an instant become steam; on the contrary, the evaporation goes on slowly. That fluids during evaporation absorb caloric, is proved by a very simple experiment. Put some water into a flask A, in which there is a thermometer filled with oil or mercury; place this over a lamp, the thermometer gradually rises, till the fluid begins to boil. If the height of the instrument be marked, it will be found not to vary in the slightest degree. Suppose it stand at 212. After leaving it there for some time, draw it into the upper part of the flask, so as to have it surrounded by the steam B, the temperature will be found to continue the same, at 212. Here, then, caloric was at first flowing in, in a certain ratio, by which the water was brought to the boiling point. It must have continued to flow in afterwards in the same ratio, yet the temperature of the water, or of the steam, is not affected; it must therefore be absorbed.



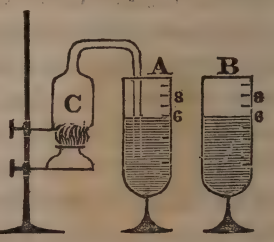
The same is proved by the experiments with Papin's digester, already mentioned. When the temperature of the water, and of course of the vapour over it, was brought to 400, and the stop-cock opened, steam rushed out with great force, and at the same time the water itself and also the steam were suddenly reduced to 212; the caloric, the loss of which had lowered the tempera-

ture of both nearly 200, having been absorbed by the steam. Dr Black endeavoured to ascertain the quantity that entered in the following way. He put equal parts of water at 50 into tin vessels, and exposed them to a steady heat. In four minutes it began to boil, and in 20 it was all evaporated; so that in the first 4, it had acquired as much caloric as raised it 162, and during the last 16 it must have received it in the same ratio, consequently in all as much had entered, as would have raised the fluid 810. Mr Watt has estimated it higher. In one experiment, water was boiled for half an hour in Papin's digester, during which it lost half an inch of its depth. The stop-cock was then shut for the same time, at the end of which the fluid had arrived at 400. The cock was then opened, steam rushed out, and continued to do so till the water had lost an inch. From this he concluded, that as much had entered as would have affected the water 950. Lavoisier fixed it at 1000, and Dr Ure has lately made it 967.

When fluids evaporate spontaneously, they also absorb caloric. It is well known, that when the hands are wetted and exposed to the air, they feel cold, because the moisture passing off in vapour, is constantly withdrawing caloric from them. This may be shown also, by covering the ball of an air thermometer with muslin, and pouring a little ether on it; it will quickly evaporate, and the instrument will indicate cold. When also fluids are made to evaporate under *diminished pressure*, cold is produced, they must therefore absorb caloric. Thus, if a ball of a thermometer, covered with muslin, be so placed under the receiver of an air-pump, that ether can be allowed to fall on it drop by drop, on withdrawing the air the evaporation goes on quickly, and a sufficient degree of cold is produced actually to cause the mercury to be frozen. Numerous other instances might be given, but for these, *see Sources of Cold.*

It may be expected, that as there is an absorption of heat during evaporation, there should be an evolution of it when vapour is condensed; and this is actually the case, as

has been proved satisfactorily, with respect to water. By the addition of equal weights of boiling water and steam to any body, the temperature is very differently affected, that which receives the steam becoming the highest. Take two graduated vessels, A and B, and put into each 6 ounces of cold water. Place a retort with a bent neck C, with water, over a chauffer, and when boiling, put the mouth of it into the jar A.



As the vapour comes into contact with the cold fluid, it is instantly condensed, and converted into water: so that, by measuring the water formed, we know the quantity of steam added. Suppose that we continue the experiment till the fluid rises to the mark 8, we have added 2 ounces of steam; we have then to pour in boiling water into the other jar, to the same height. If a thermometer be now put into them, it will be found that the temperature of that which has received the steam is much higher than the other. Here, then, we have added equal weights of water and of steam, both at the same heat, (and that they are so, the experiment with the flask and thermometer shews,) yet that which received the steam has its temperature highest; it must, therefore, have acquired most caloric. The steam, then, during its condension, must have given forth heat; in fact, it gives out that which it previously had absorbed during its formation.

On this principle it can be explained, why the hand can bear with impunity air at 212, but is instantly scorched by steam, the steam being condensed by it, and giving forth a large supply of heat.

That vapours and gases contain a large quantity of caloric, is also shewn by suddenly compressing them, or by making them lay aside their gaseous form, by entering into combination. Thus, if air be suddenly compressed, as in forcing it into an air gun, heat is evolved, and by a particular contrivance it has been found, that

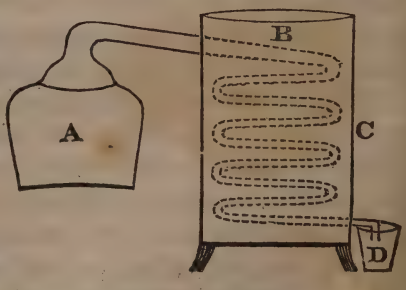
the rise of temperature is sufficient to set fire to inflammable bodies. *(See Sources of Heat.)* The same is the case, if two gases be made to enter into union. Thus, if chlorine and ammoniacal gases be mixed, there is an immediate action; they lay aside their gaseous state, forming the powder of muriate of ammonia, and the hydrogen of the ammonia is inflamed, the heat which kindles it being set free during the condensation of the gases.

The same remarks apply to the absorption of caloric during evaporation, as to fluidity. Dr Black supposed, that the water having arrived at its boiling point absorbs heat, which thus makes it assume the form of vapour, the absorption being the *cause* of the evaporation, and the caloric of course becoming *latent.* Thus, he supposed that ice with a certain quantity of caloric formed water, and that with more it became vapour. Dr Irvine on the contrary maintained, that the caloric goes to satisfy the increase of capacity; that when water is brought to its boiling point, it is converted to vapour, and at the same time its capacity for caloric is increased, hence it requires more to keep it at the same temperature; it therefore absorbs it, the absorption being the *consequence* of the change of form. According to Black, when a vapour is cooled, that is, when heat is withdrawn, it becomes fluid or solid, giving forth its latent heat; whereas, according to Irvine, having reduced the temperature, the vapour becomes fluid or solid, the capacity is lessened, it requires less than before to keep it at that temperature, and part of it is therefore set free; so that as with the absorption, according to the former, the disengagement of heat is the *cause*, according to the latter, it is the *effect* of the change.

The general law of the absorption and extrication of caloric during evaporation and condensation of vapours, serves important purposes in the economy of nature. When the earth is heated by the sun's rays, the evaporation from its surface and from collections of water is considerable, so that caloric is absorbed, and the heat which would otherwise be produced is moderated. On the contrary, as the vapour is deposited from the atmosphere,

the caloric which it had previously imbibed, is extricated, and hence the beneficial effects of the deposition of dew or hoar-frost on vegetation, and even, by this also, the intense cold that might otherwise be occasioned during night is in a great measure prevented, (see page 48.) Did this law not exist, we never could attempt to boil water; for the moment it is heated to its boiling point, the whole of it would pass off in vapour, and cause the vessel to burst with prodigious force; whereas, owing to the necessary absorption of heat, the change goes on slowly, the vapour escaping as it is formed.

The uses to which evaporation is applied are numerous and important. Many of the operations of chemistry depend on the tendency which bodies have to pass off in vapour at different temperatures. Thus, when a solid is dissolved in a fluid, they can be separated by applying heat; the latter will be evaporated, the former will remain in the vessel. When this process is carried on without wishing to preserve the fluid, it is called *evaporation;* but when it is to be kept, it is termed *distillation.* The former is practised in open, the latter in closed vessels. Thus, when the matter *in solution* is to be procured, the fluid is heated in a shallow basin, so that as great a surface as possible may be exposed, by which it is quickly evaporated. In carrying on distillation on a small scale, the fluid is put into a retort, to which a receiver is adapted, and which must be kept cold, to condense the vapour that flows into it, (see page 67.) In conducting it on a large scale, the fluid is put into a still, A, and the vapour is made to pass through a spiral tube, or *worm*, B, placed in a tub with cold water, called a *refrigeratory*, C. In this worm the vapour is condensed, and escapes at the open end, where it is collected in vessels, D.



The only fluid, the vapour of which we can put to any particular use, is water. Steam, owing to the large quantity of caloric which it gives forth during its condensation, is employed for heating apartments. For this purpose, pipes connected with a boiler are carried through the room, being, till they enter the apartment, left resplendent, to prevent the heat from being too quickly carried off, and by which the steam would be condensed. Steam is also employed for carrying on different chemical processes in which too great heat would be injurious, as in assisting fermentation, and in drying substances gradually, and without the risk of burning them. When it is used for the last of these, suppose for drying gunpowder, the powder is placed on boxes, which are filled with it, the condensed vapour being carried off by tubes. When it is employed for heating fluids, it is either condensed in them, or made to pass through them in *worms*. Thus, in heating water for baths, or in the operations of dyers, where water is used for dissolving the dye, a tube terminates in each bath, or dye vat, near the bottom, where it is condensed; it gives out its latent heat, and warms the whole of the fluid, as was the case in the experiment mentioned at page 78. In those cases, on the contrary, in which the condensed steam would prove injurious to the fluid, in the distillation of spirits, for instance, a worm passes through it, and comes out at the bottom, (as in the refrigeratory, page 80,) and being kept constantly full of steam, which is to be condensed, the latent heat is evolved, and brings up the temperature sufficient to carry on the distillation. The condensed steam escapes at the mouth of the pipe. In the same way brewers sometimes warm their fluids, for extracting the soluble matter from malt.

It must be kept in mind, that in heating by steam, the temperature cannot go beyond 212, the boiling point of water, because, when the substance is brought up to this, it ceases to condense it, so that any additional quantity thrown in, though it keeps up the temperature, cannot carry it higher.

Incandescence, or Ignition.

The three general effects of caloric already treated of, may be considered as different degrees of the same law,—that it has a tendency to make the particles of a body recede, the separation increasing according to its addition. The fourth effect is quite distinct. By *Incandescence*, or *Ignition*, is meant, that substances, when heated to a certain temperature, become red hot, or they emit *light* as well as heat.

Incandescence is not accompanied with any chemical action, and must therefore be distinguished from combustion, which is the result not only of the addition of caloric, but of an action between the air and the body, which, when it has ceased, no longer remains combustible. Ignition, on the contrary, is altogether independent of the air, and is continued as long as the temperature is kept up, and may be renewed at pleasure.

The point of the thermometer at which bodies become incandescent is differently stated by authors, yet it seems to be the same in all; of course it must vary according to circumstances, particularly with respect to light; an object which is red hot in the dark not being so in day light. Sir Isaac Newton fixed the point of incandescence in the dark at 635; but this is too low, for mercury boils at 656, and is not incandescent. Other experimenters have placed it at about 790, while Wedgewood has made it about 950. It is now generally supposed that ignition in the dark occurs at about 800. As the heat is increased, the emission of light also becomes greater, and the colour changes first into red with an admixture of yellow, and lastly into bright white, beyond which there is no change. The degrees at which these occur have not been ascertained with accuracy. Newton has placed the full red heat at about 750, and incandescence visible in day light at 1000, while Wedgewood has fixed it at 1077. The former, it has been already said, has made ignition in the dark too low; we cannot, therefore,

place much confidence in the results of the experiments on this subject.

The temperature necessary for making fluids, but more particularly gases, incandescent, is above that of solids; and that gases do assume this state, is evident from the light given out during many cases of combustion, flame being merely incandescent gaseous matter, the heat which has brought them to the proper temperature, being evolved by the chemical action accompanying the combustion.

Bodies may be made red hot by friction and percussion, as well as by the direct application of heat. Thus, if two hard substances, as flint and steel, be struck together, small sparks fly off; or if a piece of hard metal be rubbed against a stone, as in the familiar instance of a grinding-stone, it becomes red hot. This is, of course, to be ascribed to the heat excited by the friction and percussion being sufficient to elevate their temperature to that of ignition, as it is well known that caloric is evolved during these processes. (For the farther consideration of this subject, *see Light.*)

Sources of Heat and Cold.

From the tendency which heat has to diffuse itself, till there is an equality of temperature, it would soon be established over the earth, were it not for the constant operation of foreign powers; the changes that occur are, however, not great, the extremes of heat and cold that would otherwise ensue, being prevented by the same causes. The range of natural temperatures is by no means extensive. The average heat of the globe is about 50, the extremes not being many degrees above or below this. In warm climates, the thermometer occasionally stands at 110 or 115 in the shade, while, in the colder regions, it sometimes falls to —50, thus making a difference of about 160 or 170 degrees. The range of temperature which we can procure by artificial means, is luckily much

greater, the lowest cold, accurately measured, being —91, or 123 below the freezing point; while the greatest heat, also accurately ascertained, was 153 W. which, if we place reliance in the pyrometer, must have been 24,000 F. Higher and lower degrees have been produced, but the temperature of these has not been ascertained.

This brings us to the last part of the subject of Caloric, the means of producing a change of temperature, or what is commonly called, the *generation of heat and cold.*

Means of Generating Heat.

The different methods of generating heat, are the *Solar Rays*, *Electricity and Galvanism*, mechanical action between solids, as *Friction* and *Percussion*, and *Chemical Action*, under which is included *Combustion.*

The principal source of the heat of this globe is the solar rays, which are constantly passing from the sun to the earth, and warming it, or any other dense object on which they strike. The heat produced in this way, in the open atmosphere, is by no means high, but it depends in a great measure on the nature of the object on which the rays strike, and that it is so, has been proved by the experiments of Franklin and Davy. Franklin, by exposing pieces of different coloured cloth on snow, found, that when the sun's rays acted on them, they sunk into the snow, just in proportion to their darkness, black sinking by far the most. Similar experiments were performed by Davy (Beddoes' Contributions.) He took equal pieces of copper, and painted one side of them white, yellow, red, green, blue, and black, and on the opposite side was placed a small piece of cerate. On exposing the painted sides to the sun's rays, he found that the cerate was first melted on the blackened, next on the blue, then on the green and red, next on the yellow, and lastly on the white; owing of course to the difference in the absorption, the blackened one absorbing most, the white least, in other words reflecting powerfully.

The heat produced by the solar rays may be increased by

particular means. In an experiment in which Saussure enclosed the bulb of a thermometer in a box of cork, and charred in the inside; on allowing the rays to flow on it, the temperature rose to 221: and Professor Robison found that he could by a similar contrivance produce a heat of 237, while that of the atmosphere was only 73. By other methods, a much more intense heat can be produced, as by concentrating the rays by mirrors and lenses. The large lens made by Parker very easily fused silver and gold, and caused them to pass into vapour. Hence this affords an easy method of trying the effects of an intense heat on different bodies, as when they are confined in gases. A very high temperature is also excited by common mirrors, as those used for radiation; they are however subject to this objection, that as the rays are directed upwards, when the substance on which they strike begins to melt, the application of the heat must be discontinued.

Rumford has shewn that a lens and mirror do not act, as some supposed, by augmenting the power of the rays, but merely by causing a greater number to act on the same spot; for he found that, in directing them on a blackened flask, the water in it was brought to the same temperature whether the rays were dispersed over its surface, or concentrated by a lens.—(Jour. de Phys. lxi. 32.)

Electricity and Galvanism produce a very high temperature. By them, more particularly by the latter, metals may be made red hot, and even converted to vapour; and by the former, gaseous bodies are easily inflamed, *(See Electricity and Galvanism).*

Friction and Percussion are also sources of heat. That heat is evolved by friction is well known, and that the temperature is intense, has been proved by many experiments. By rubbing two pieces of wood together, by the friction of a rope over a pulley, or of the axle of a carriage, combustion is often produced. In this way forests have been burned by the violent friction of the branches against each other during storms. The wheels of machinery, and ships also, by the rubbing of the cables against the sides during the lowering of the anchors, have been set

on fire. The temperature produced in these instances does not depend on the hardness of the bodies employed, as it is generally remarked that the softest woods occasion the greatest heat.

The heat excited by percussion is equal, in many cases it is superior, to that evolved by friction. If a piece of iron be struck against flint, or two flints against each other, small sparks are thrown off. A familiar instance of the generation of heat by percussion, is the method a blacksmith often resorts to for kindling a fire. He places a small rod of iron on the anvil, and strikes it repeatedly and forcibly with his hammer, by which, in a short time it becomes so hot, that a sulphur match may be easily kindled by it.

Under the production of heat by mechanical means, may be mentioned the method of generating it by suddenly condensing atmospheric air. In working the syringe, by which this is compressed into an air-gun, it is always found to become warm. In this case much of the heat evolved must depend on friction; a sufficiently high temperature can, however, be produced by the sudden compression of air, to set fire to inflammable bodies, on which depends the instantaneous light-giving syringe, much used on the continent, for affording a light. It is merely a small brass tube, A, to which a piston, B, is accurately adapted, and at the end of which, C, there is a cavity for containing the tinder. That employed is the substance called *Amadou*, which is a fungous excrescence growing on some trees, and beat till it becomes quite spongy, and afterwards soaked in nitre. A little of it is placed in the cavity at the end of the piston, which is put into the syringe, and driven forcibly home; and the heat evolved during the sudden compression of the air, is sufficient to kindle it. Of course the piston must be withdrawn quickly, otherwise the amadou, though kindled, will be extinguished.



The evolution of heat during the condensation of gases,

is supposed to be owing to a diminution of capacity which the substance suffers, as it is well known that the nearer the particles of a body are brought to each other, the capacity in general becomes less. The disengagement of it by percussion is probably to be accounted for in the same way. When a body is repeatedly struck, its specific gravity is increased; there must therefore be a condensation, and as this is known to lessen the capacity for caloric, part of it may therefore be disengaged. It must not be supposed, however, that all the heat that becomes sensible in these cases is owing to the condensation, for when flint is struck against steel, small sparks fly off. Here the caloric evolved by the condensation, has been sufficient to raise the temperature of the detached piece of steel, to that at which it will unite with part of the air, by which heat is also disengaged. Hence iron, when struck against flint *in vacuo*, does not produce sparks.

The evolution of caloric by friction, cannot be accounted for in the same way. It is well known, that there is no condensation when soft bodies are rubbed, nor is there any action between them and the air, as heat is evolved in this way *in vacuo*, and even under water. Some have supposed that it depends on electricity. Thus, in an experiment of Pictet, in which hard substances were rubbed together in a vacuum, a thermometer placed between them indicated a rise of temperature; but when cotton was introduced so as to prevent the instrument from being broken, and when the fibres rubbed against the bulb of the thermometer, a much greater heat was excited than before. (Pictet sur le Feu.)

The most abundant source of heat, and that applied to the most useful purposes, is Chemical Action. By the mixture of different substances, a chemical action is induced, which is generally accompanied with a change of temperature, frequently with the evolution of caloric. Thus, when oil of vitriol and water, in equal quantities, are mixed, a sufficient heat is excited to set fire to inflammable matter. If, for instance, some tow,

with a piece of phosphorus in it, be wrapt round the glass, and the mixture be stirred, it is instantly kindled. The same also happens when water is thrown on recently burned lime; they enter into union, and heat is disengaged.

Numerous other instances of a similar nature might be given, but this method of generating heat is not put to any particular use.

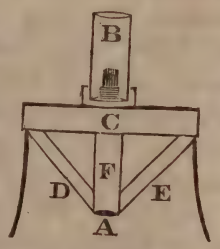
From what has been already said, when treating of fluidity and evaporation, it is evident that the disengagement of heat in these instances is owing to the change of form, which one or both of the substances experience, and by which, according to Black, the latent caloric is set free, or, according to Irvine, there is a diminution of capacity; so that the bodies require less when combined than when separate. In those instances in which there is no change of form, there is a condensation, as happens to sulphuric acid and water, the mixture occupying less space than the ingredients; and hence, also, the cause of the disengagement of heat.

Dead animal and vegetable matter, under certain circumstances, undergo a change called *putrefaction*, during which heat is evolved, but this mode of producing it is resorted to only by farmers and gardeners. Horse dung, and oak-bark after being used by tanners, are the substances generally employed. The former, when there is a large collection of it, will excite heat of about 140, which it continues to do for a long time; and hence its use by gardeners in making hot-beds. Tanner's bark is employed also for the same purpose.

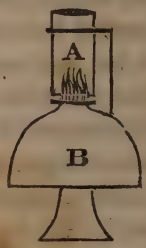
By far the most important source of heat, is combustion. Before proceeding to treat of the generation of heat by it, it may be remarked, that it is occasioned by a chemical action between an inflammable body and the air of the atmosphere; of course, a supply of the latter is absolutely necessary, and the more freely it is admitted, the more rapid is the combustion, hence many of the improvements which have lately been introduced for increasing the heat during this process. Till within

a short time, the only inflammables were solid or fluid, but of late an aeriform substance has been used, with which a most intense heat can be excited. The fluid combustibles in general use are, alcohol, oil, and tallow, for the latter, though solid at a natural temperature, is liquefied before it is burned. It is of great consequence, in the combustion of these, that the heat be steady, and that there be no unnecessary waste of the materials; for this reason it is usual to burn them on a soft combustible, as cotton, by which the fluid is drawn up, and gradually consumed. In the case of tallow, the heat given out by the burning of the cotton, and afterwards by its own combustion, melts it, and thus allows it to be burned in the same way as oil. The flame caused by the combustion proceeds from an inflammable gas given out, which unites with part of the air of the atmosphere; where this is not in contact with it, it is of course not consumed, and hence the cause of smoke, which is merely the carbon that exists in the gas, deposited from it in the state of a very fine powder. To prevent this, three different methods are adopted. 1*st*, To use a very small wick. 2*d*, To have a flat wick, as is commonly employed in kitchen lamps. 3*d*, To have the wick hollow, which is by far the greatest improvement that has been made. This was recommended by Bolton, but introduced by ARGAND, and hence lamps with it are called *Argands*.

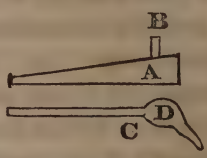
By using a hollow wick, there is a constant current of air through it, entering at A, by which the whole of the flame is brought in contact with it, and the inflammable matter is consumed, and smoke prevented. To increase the draught through the wick, it is necessary, also, to surround it by a cylinder, B, by which the air is more freely supplied, and the combustion more complete. C is the part of the lamp for holding the oil, which is conveyed by the tubes D and E to the wick in F. Though



this mode of consuming oil is employed principally for affording light, yet it is a good method of supplying heat, particularly to small vessels. In using it for this purpose, the wick is surrounded by a copper cylinder, B. By placing a cylinder A, over a common lamp B, the flame becomes much steadier, and the smoke is in a great measure prevented; so that this, also, forms a good mode of applying heat on a small scale.



It has been already said, that the renewal of air is absolutely necessary for combustion, and the more freely it is admitted, the more rapid is the consumption of the combustible; *hence the heat may be greatly increased by causing a blast through the flame.* For this purpose, a blow-pipe, to be blown either by the mouth, or by bellows, is used. It is of very little consequence what form of pipe is adopted, though different kinds have been recommended by different people. Dr Black used one of a conical form, A, made of tinned iron, with a pipe coming from the side near the base B, and terminating with a very small aperture. C is the form of the common glass blow-pipe, the ball D being intended to condense the moisture in the air coming from the lungs. By causing air to pass through the flame, it is drawn to a fine point, at which a most intense heat is excited. In using the lungs as the means of procuring the blast, when these are nearly exhausted of air, the mouth must be filled by distending the cheeks; and by afterwards compressing these, the air is expelled through the pipe, while it may at the same time be taken in through the nostrils, so that a continued blast can be kept up for a long time. When the lungs cannot be used, recourse is had to double bellows. These are merely two bellows, A and B, joined, with an opening leading from one to the other, C, over which there is a valve, the same as in common bellows, there being also a valve at the opening of



the other, D. On the upper one there is a weight E, and from it proceeds the pipe F. When the lower one is filled by moving the handle G, the air is thrown into the upper, from which it is constantly rushing through the pipe, being forced out by the pressure of the weight, so that in this way an uninterrupted stream is kept up. These apparatus are much employed by glass-blowers, and they are also extremely useful to chemists. Double bellows are much used also by blacksmiths and others, when an intense heat is required.



The principle on which the blowpipe acts, is by bringing a constant supply of air to the inflammable matter, thus rendering the consumption more complete, and the consequent heat greater. *See Berzelius on the Blow-pipe, translated by Mr. Children.*

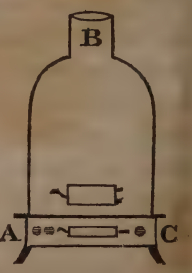
It will be afterwards shewn, that the air of the atmosphere is a compound, containing two ingredients, only one of which supports combustion, so that if, instead of using air as the means of keeping up the blast, the purer part of it or *oxigen gas* be employed, the heat is much more intense. It will be afterwards shewn also, that instead of using oil as the inflammable, if the light aerial fluid hydrogen be employed, a very high heat may be excited, perhaps the most intense we have yet been able to procure. *See Hydrogen.*

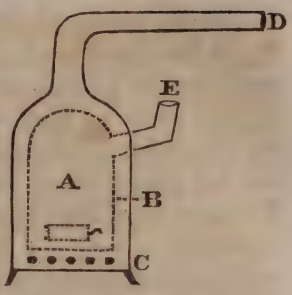
The next class of combustibles is the solids, which are wood, charcoal, peat or turf, and coal. In those countries in which wood abounds, it is the principal fuel. Its combustion is lively, but it gives out a great deal of smoke and flame, which render it unfit for many operations, so that it is confined chiefly to the heating of apartments, but it is employed also by some, as by bakers, in their ovens. When, however, it is converted to *charcoal*, these inconveniences are prevented, and it is then useful, as a means of generating heat, for many purposes of the arts, being employed by dyers, confectioners, and

many others, and it is also much used by chemists. Peat, or dried turf, is likewise used as fuel, but chiefly in those places where the others cannot be obtained. Coal is by far the most useful of the inflammables, and is employed in almost every operation where an intense heat is required on a large scale. It is used in two states, either as procured from the mine, or in the form of *coke*, which is prepared merely by exposing it to heat, excluded from the air, by which it is deprived of those substances that are the cause of the flame and smoke. Coal is burned principally in open fire-places, for heating apartments. Coke is employed when heat is required for carrying on different operations.

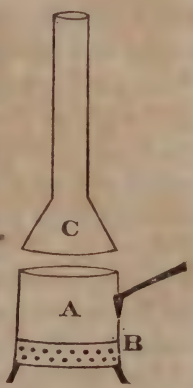
When fuel is burned in a grate, the heat that enters the apartment is that emitted by radiation; the whole of the warm air escaping up the vent, because that in contact with the fuel being heated, becomes lighter, and ascends. The more rays, then, that can be thrown into the room, so much the better. Rumford has therefore proposed, that the sides of the fire-place be made of some material which reflects the radiated heat, and that they be so situated, as to throw off as many rays as possible; hence they are now placed in a slanting direction, instead of being square with the back, as formerly, by which there is not only less fuel consumed, but our apartments are better warmed, and smoke is in a great measure prevented, because, as the fire-place is narrower, there is a greater draught up the vent.

Coal is sometimes also burned in a stove, for heating apartments. A stove is merely a grate, but confined on all sides, the air necessary for combustion entering through the apertures below, A, in the ash-pit C, and the smoke passing up through a tube from the top, B. In this way of burning fuel, the supply of air is not great, consequently there is not much change of that in the room, which makes it feel disagreeable to those not accustomed to it.

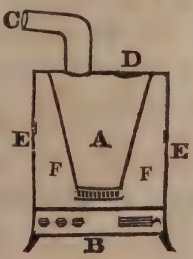




A particular modification of a stove, is well adapted for warming large places, as churches and manufactories. It is merely a common stove, A, surrounded by an outer covering, B, at the distance of a few inches, with openings below C, to admit air. When the stove is kindled, and becomes hot, the air that enters through the outer part striking it, is instantly heated, and, becoming lighter, ascends, being forced up by the colder particles rushing in to supply its place, and may thus be conveyed by tubes, D, through the room, or even to the different apartments of a building, the tubes, till they reach the apartment, being made of a resplendent metal, as tinned iron, that they may give off little heat by radiation.—*(See page 45.)* The smoke is carried off by the vent E.



Coke is burned in chauffers, or furnaces. A chauffer is merely a cylindrical box of sheet iron, A, open above, and with a grating at the distance of about an inch from the bottom, B, for supporting the fuel, the air for the combustion entering at apertures below. These are well adapted for applying heat to small vessels. By putting on a vent, C, it becomes very intense, and this is often used when we wish to apply a strong heat to substances placed amidst the fuel, as in crucibles.



Furnaces are of different forms according to the use to which they are applied, but in their *general* construction they are the same. A furnace consists of three parts ; a body, A, with a grating for holding the fuel, an ash-pit, B, in which the openings for the admission of air are generally placed, and a chimney,

C, for the escape of the smoke. There is also an opening in the upper part, D, into which a pot for holding sand can be placed, and by which heat is applied very equally when we wish to carry on distillation. There are also holes in the sides, E, E, through which tubes can be passed when we wish to subject gases to heat. Furnaces on a large scale are of the same general construction; a body for holding the fuel, an ash-pit, and a vent,—but different forms are used, according to the use to which they are applied.

The combustion in furnaces, and the consequent heat, depend on the supply of air to the burning body; the quicker its renewal, the more rapid its combustion, and, of course, the more intense the heat. The rapidity with which the air is made to enter, is increased in two ways, either by enlarging the openings for its admission, or by lengthening the chimney. When it is required that the heat should be very strong, the vent is carried to a great height, by which the air is made to enter rapidly, and the fuel is quickly consumed. This is occasioned by the air in the vent being lighter than that without; it therefore rises to make way for its admission below. So long, then, as the air in the vent is enlarged, it is pressed up by the heavier colder particles. When, however, the chimney is so long that the air within and without are of the same density, there is no farther increase of the rapidity with which it enters, though the vent is made higher. The longer, then, that the air can be kept warm, so much the better, because it is expanded, and lighter than that without. Hence chimneys, even though short, are made of bad conducting materials, to allow the air in them to cool slowly,—in other words, to contract slowly.

In the construction of furnaces, it is of the utmost consequence that the heat be as much confined as possible. On a large scale, they are made of bricks, and sometimes lined with fire clay. Smaller furnaces, as those made of metal, are always lined with a mixture of clay and sand, or with charcoal and clay, and

afterwards with clay and sand, F, F, to protect the charcoal from the fire, which not only confines the heat, but prevents the destruction of the furnace. *(See preceding cut.)*

Means of Generating Cold.

By the generation of cold, it must be kept in mind, is meant merely the abstraction of caloric.

The methods inducing a reduction of temperature are, *Rarefaction, Evaporation, and Chemical Action.*

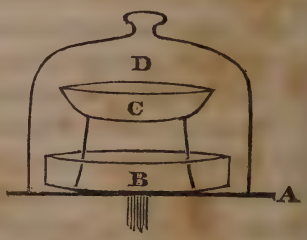
When an aeriform body is suddenly rarefied by part of the pressure being reduced, cold is excited. If a delicate thermometer be placed in the receiver of an air pump, and the air be quickly withdrawn, it indicates cold; or if it be held in the stream of air as it rushes from an air-gun, into which it had been previously condensed, and by the escape from which it is rarefied, the temperature sinks. Perhaps the most remarkable instance of the reduction of temperature by rarefaction is that mentioned to have taken place at Chemnitz in Hungary, where, to procure a blast for animating a furnace, air was compressed by a column of water of 260 feet. On opening the stop-cock, the air thus condensed rushed *out* with immense force, and the watery vapour existing in it was deposited in the form of icicles around the nozle of the pipe.

The production of cold by rarefaction is to be accounted for in the same way as the generation of heat by condensation; the rarefied air absorbing caloric, which becomes latent, or having its capacity enlarged, by which it acquires an additional quantity of heat.

It has been already fully explained, when treating of evaporation, that when a fluid is converted into vapour, it absorbs caloric.—(See page 77.) If this be not supplied, it must take it from itself, or from any body brought in contact with it, and hence generates cold. When, for instance, the hands are wetted, and exposed to the air, they feel cold, because the water, during its evaporation,

absorbs heat from them. That cold is generated by this process, is proved also by covering the ball of an air thermometer with muslin, and pouring a little alcohol or ether on it; the fluid in the stem instantly rises, owing to the contraction of the air in the ball, and thus indicating cold. If the bulb of a common thermometer, after being covered with muslin, be dipt in ether, and whirled in the air, its temperature falls considerably.

It has been already proved, that as the pressure on a fluid is diminished, it evaporates more easily than when exposed to the air, and hence a method of increasing the rapidity of the evaporation, and consequent reduction of temperature. By placing water under the receiver of an air-pump, and exhausting, the fluid evaporates, but the vapour formed itself exerts a pressure on the water; so that, unless we keep constantly working the pump, the evaporation ceases. There is an easy method, however, of keeping up the vacuum, without working the pump, which is, to place a vessel with oil of vitriol under the receiver, which, owing to its powerful attraction for water, condenses the vapour as it comes off. We are indebted to Professor Leslie for this method of generating cold. He places on the plate of the pump, A, a basin with oil of vitriol, B, and over this a small unglazed earthen-ware dish, C, with water, resting on a stand. The receiver, D, is then put on, and exhausted. The water being under less pressure than before, evaporates, and the vapour is quickly condensed by the acid, so that the vacuum is kept up, the evaporation continues, and the vapour, during its formation, absorbs caloric from the water, reduces its temperature, and actually makes it freeze. Though the water is covered with a layer of ice, still the evaporation and absorption of heat continue, for the ice itself is changed to vapour; indeed, if we keep it long enough under the receiver, the whole of it is

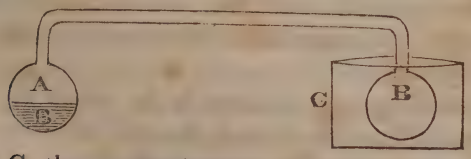


frozen, and afterwards disappears, being converted to vapour, and condensed by the acid. In this experiment an unglazed dish is used for holding the water, because, being porous, it allows the fluid to evaporate, not only from the surface, but also through the sides; hence the ice is first formed on the surface, and on that part in contact with the vessel.

Instead of sulphuric acid, other substances may be used. Oat-meal, well dried, and many other bodies in the state of powder, have a similar, but not so powerful an effect.

The generation of cold under diminished pressure may be shewn also, by placing a small tube with water into a glass of ether, putting it under the receiver, and exhausting. As the air is withdrawn, the ether begins to pass off in vapour, and reduces the temperature of the water, so as to cause it to freeze, affording the singular appearance of two fluids in the same jar, one of which is boiling, and the other freezing.

Another very beautiful illustration of the production of cold during evaporation, has been given by Dr Wollaston. The instrument employed is called a *Creophyrus*, (κρυος, cold, and φερω, to bear.) It is a tube, forming three sides of an oblong, with a ball at each end. In making it, water is put into both balls, and boiled for some time, by which the whole of the air in the instrument is expelled, and when in this state, it is sealed by a blow-pipe, so that, when cooled, the fluid is under a diminished pressure; but it must not be supposed that the pressure is *entirely* removed, for there is still the vapour given off from the water. If the whole of the water be put into one ball, A, and the other, B, be surrounded by a freezing



mixture, C, the vapour in it is condensed, the water, D, in the other, is thus entirely relieved of pressure, and

begins to pass off quickly in vapour, which, as it flows into the opposite ball, is condensed. The vacuum is thus kept up, the evaporation continues, and during the formation of the vapour, it absorbs caloric from the water, so as to cause it to freeze.

If the creophyrus contain ether, and the ball, A, be put into a basin of water, B, being surrounded by the cold mixture, as the ether is drawn off in vapour, the fluid in the basin begins to freeze, and in the course of a short time, A is covered with a thick layer of ice. All of these experiments are farther proofs of the general law, established by Dr Black, that as fluids pass into vapour, they absorb caloric, and the absorption must be very great, because there is not only the reduction of temperature to the point of congelation, there is also the abstraction of the latent heat of the fluid which is frozen.

The last method of generating cold, is chemical action, chiefly when a solid is dissolved in a fluid, or when two solids act on each other, and become liquid. The absorption of caloric during liquefaction has been already fully illustrated, (p. 59.) If, then, we can, by any means, cause a solid to become liquid, without the addition of heat, we diminish its temperature, and consequently that of any body brought in contact with it.

Many of the salts, during solution in water, have their temperature reduced. Thus, nitre falls 17, and sal ammoniac no less than 28 degrees. By mixing these in equal proportions, and dissolving them, using five ounces of the mixture to eight of water, a much greater cold may be produced. That cold is generated, is easily shewn by a thermometer, or by putting into the mixture a tube with water, which is soon frozen. In this case, there is no waste of materials, because the salts can be procured by evaporation, and will answer again for the same purpose.

By dissolving a salt in an acid, by which the solution is more quickly accomplished, the cold becomes more intense. Perhaps the most convenient mixture of this kind is Glauber salts, and oil of vitriol previously diluted with its own volume of water, and allowed to cool.

When the salt is put into this, using equal weights, it is quickly dissolved, and the temperature falls.

By the action of two solids, the product being fluid, the cold becomes still more intense. Thus, when ice is mixed with sea salt, both are liquefied; and during their liquefaction, they absorb caloric, and of course generate cold. In this instance, the temperature sinks to —4. It is the mixture always employed by confectioners in preparing ice creams; the proportions being about two of the former to one of the latter; and here also there is no waste, for by boiling the water is driven off, and the salt is procured, and will answer for the same purpose as before. This is also the mixture employed by Fahrenheit, in his experiments, made with a view of producing what he conceived to be the degree of absolute cold, or that at which there is no heat, and from which he commenced the scale of his thermometer. In this he committed a mistake, not only with respect to the temperature, for it is not 0, but —4, but he erred also in his idea of its being absolute cold. It has been already stated, that lower degrees have been produced by other means. Another salt, which acts very powerfully, is muriate of lime, which, when mixed with snow, produces a great reduction of temperature.

By these different means cold is produced; and by cooling the articles previous to their being mixed, the reduction of temperature becomes still greater. By mixing snow and sulphuric acid, diluted with half its weight of water, both being cooled by being placed in a cold mixture, a cold of —91 was obtained by Mr Walker of Oxford.

In all these instances, the generation of cold is to be ascribed to the change in form, one or both of the substances becoming fluid, and, according to Black, taking in latent caloric; or, according to Irvine, having, by the chemical action, their capacities suddenly increased, by which the heat in them is no longer able to keep them at the same temperature; consequently, they take it from any body brought in contact with them.

Those bodies which act most rapidly on each other, and thus quickly become fluid, and at the same time absorb the greatest quantity of caloric, have most effect in generating cold. Thus, one which is but slowly dissolved in water causes little reduction of temperature, while those which dissolve quickly produce a more intense cold. When two solids become fluid, the absorption of caloric is greater, and the temperature sinks still farther. But besides this, it is necessary also that the product remain liquid, at a low temperature; otherwise the action, and the consequent reduction of temperature, cease. Thus, by muriate of lime and snow, a cold of —50 can be produced, while by mixing sulphuric acid and snow, the temperature falls only to —25. In the former, the reduction cannot be made to go beyond that stated, because when it has come to this the solution congeals, and the substances cease to act on each other. In the latter, however, the product remains liquid at a very low temperature; consequently, if they be cooled before they are mixed, the cold becomes much more intense. Hence has arisen a method of increasing the cold by the previous cooling of the substances, by putting them into other freezing mixtures. This, however, has also its limits, for if we cool them below the temperature at which they act on each other, there is no farther reduction when they are mixed. Thus, muriate of lime and snow produce a cold of —50; but if these be cooled to this, and mixed, it does not become greater, because they do not act on each other.

It must be kept in mind, that, in many instances, the reduction of temperature is in a great measure counteracted by the condensation, and consequent evolution of caloric. Thus, when two bodies act, and become fluid, there may be a condensation, owing to the fluids uniting, and by which heat is disengaged; but, at the same time, during the liquefaction, caloric must be absorbed: now, if cold is the consequence, it is because the heat given out by the condensation, is not equal to that absorbed by the liquefaction, as is well illustrated by sulphuric

acid and snow. It has been already said, that this acid and water uniting, give out heat, owing to condensation; when the acid is poured on snow, the latter is liquefied; and, of course, there is an absorption, so that by using different proportions, we may have either a rise or fall of temperature. Thus, if 4 of acid be poured on one of ice, heat is produced, because, though the ice, during melting, absorbs caloric, yet the water and acid uniting, give out during their union, and consequent condensation, much more than is necessary for this.—On the contrary, if 1 of acid and 4 of ice be used, we have a freezing mixture, because more caloric is taken in than is given out, the quantity of ice being great.

We have an easy means, however, of obviating this counteracting power, which is, merely to unite the substance with a little of that with which it is to cause the condensation. Hence, in the instances already mentioned, in which sulphuric acid is employed, it is diluted with water, and allowed to cool before it is used. For the same reason, also, in dissolving Glauber salts in oil of vitriol, with the view of making a freezing mixture, it is necessary to dilute the acid before putting the salt into it, to prevent it uniting with the water, which always exists in the salt, and thus giving out heat.

The instances in which we have recourse to a reduction of temperature, are by no means so numerous as those in which heat is applied. In warm climates, evaporation is often resorted to for cooling apartments, for which purpose water is sprinkled on branches, and leaves of plants suspended in the room, during the evaporation of which the air is kept agreeably cool. Ice is also procured, by the cold generated during this process. When the evening is calm, and the sky clear, small unglazed earthen dishes, with water, are placed on straw and reeds, laid in shallow pits, and the evaporation generates cold sufficient to form ice. It must be recollected, however, that in this case, a great deal of the cold is due to radiation; because the sky being clear, the water and reeds

are radiating caloric, and as there is no return to compensate for the loss, the temperature falls, *(see page 47.)* We have often recourse to evaporation for keeping bodies cold, as in carrying on distillation. For this purpose, the vessel into which the vapour flows is covered with muslin or paper, and kept wet by a stream of water, which is constantly evaporating, and thus cooling the vapour within, *(see page 67.)* *For Table of Freezing Mixtures, see Appendix.*

SECTION II.

LIGHT.

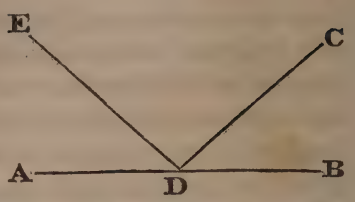
The consideration of this subject more properly belongs to Mechanical Philosophy than to Chemistry. A short account of it is, however, necessary, to enable us to trace the connexion between it and heat, and to understand the nature of the chemical changes it induces.

Light, like caloric, is an agent which we cannot procure in its separate state; we know, however, that it enters into union with substances, and that it is set free when these form new combinations, so that, in treating of it, we can only point out its effects, and the circumstances attending its absorption and evolution.

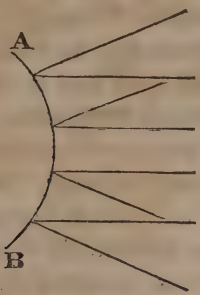
Light moves in straight lines with immense velocity. According to observation, it travels at the rate of 200,000 miles in a second, coming from the sun to the earth, a distance of about 8,000,000,000 of miles, in $8\frac{1}{4}$ minutes. Though it moves with this velocity, it has no sensible momentum; the most delicate instruments do not indicate the slightest impulse given by it to the objects on which it strikes.

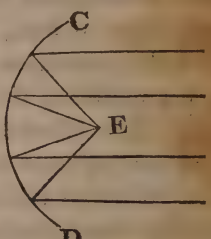
The space through which light moves is called a *medium.* Air, and other aeriform substances, are termed *rare*, while water, and transparent liquids and solids, are called *dense* media.

When light strikes a polished opake body, it is *reflected*, and at the *same angle* at which it falls on the polished object. Thus let A B, be a plate of metal, and C D, a ray of light; the moment it touches the plate, it is thrown off in the direction of D E. The angle C D B, or that at which it strikes the plate, is called the angle of *incidence;* E D A, is the angle of *reflection;* hence the angle of incidence is always equal to the angle of reflection.

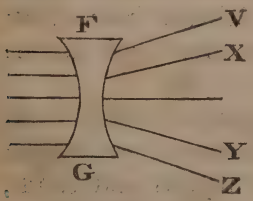


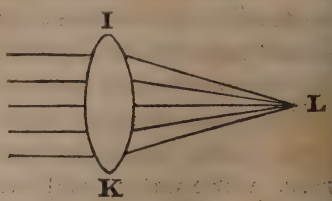
If the plate be not flat, the reflected rays are either dispersed or concentrated. Thus, if they strike a *convex* metallic mirror, A B, after reflection, they occupy more space than before; on the contrary, if the mirror be *concave*, C D, they are collected into a point, or *focus*, E.





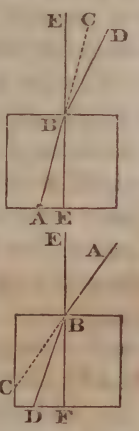
If the rays pass through the body, they are also either dispersed or concentrated, according to the surface; but the law followed is the reverse. If the body, suppose glass, be concave on both sides, F G, they are dispersed, V X Y Z; but if convex, I K, they are collected into a focus, L.

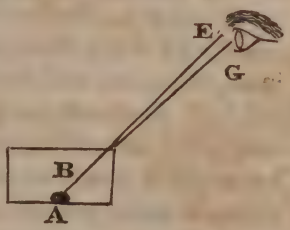




When light passes from one medium to another, unless

it be perpendicular to the surface, it is turned from the straight line. Thus, if a stick be thrust into water, it appears crooked at the surface of the latter, because the rays passing from it through the water, to the air, are bent; and as this takes place the moment they leave the fluid, it is here that the bending of the stick appears.—This is called *refraction.* When a ray passes from a *dense to a rare* medium, it is turned *from* the perpendicular. Thus, let A B represent a ray coming up through water, E F being the perpendicular; when it leaves it, it does not proceed in the same direction as before, B C, it goes on towards D; it is therefore turned from the perpendicular. When, on the contrary, a ray passes from a *rare* to a *dense* medium, it is bent *towards* the perpendicular. Thus, as before, let A B represent a ray passing through air into water, E F being the perpendicular; having got into it, it does not go on in the same direction, B C, it proceeds to D; it is therefore turned towards the perpendicular. That light, in passing from a dense to a rare medium, is turned from the perpendicular, is proved by a very simple experiment. Let a person place a piece of money, A, at the bottom of a basin, B, and retire till he just loses sight of it,—that is, till the rays A E, coming from it over the edge of the basin, reach above his eye; let another then pour in water, and the money is seen distinctly, the ray, E, must therefore strike lower than before; hence, as it leaves the fluid, instead of going on towards E, it proceeds to G, so that it enters the eye, and the money is seen.





In general, the refraction is in proportion to the difference between the densities of the media, but this is not always the case. When a substance contains an *inflammable* ingredient, it is greater than is proportionate

to the difference of the density. It was the knowledge of this that made Newton conjecture that it would one day be discovered, that water and diamond contain inflammable matter; the correctness of which has been now proved. The power of gases to refract light has been pointed out by Biot and Arrago; and in their experiments they have also found, that the inflammable gases have the greatest effect; thus, taking the refracting power of air as 10,000, that of hydrogen gas is 66,143.

Newton has supposed that these different properties of light depend on an attraction between it and the media through which it passes, and between it and the body which it strikes or approaches. It passes freely through some objects, as glass and water, which are called *transparent;* but on the contrary, it is absorbed by others, as metals, which are termed *opake.* He supposed, also, that transparency and opacity are owing to the arrangement of the particles. Thus, in transparent ones they are supposed to be of the same density, and uniformly arranged; hence, when a ray enters one of these, it is attracted equally on all sides, consequently not altered in its direction, but passes through without obstruction. In opake objects, the particles, he supposed, are either not of equal density, or not uniformly arranged; a ray therefore entering, is constantly altered in its direction, and does not go through it.

Light possesses the property of entering bodies, and combining with them, from which it is again extricated, by keeping them in the dark. The substances with which it unites are called *phosphori*, and the emission of it is termed *phosphorescence.* The shells of marine animals, bones of land animals, some of the gems, and other combinations of the earths, have this property. Thus, in an experiment in which diamond was exposed to sunshine, and instantly covered with black wax, when taken into the dark, and the wax removed, it was found to give out light for several months. Phosphori may also be prepared artificially; perhaps the most powerful of which is *Canton's Phosphorus*, obtained by exposing oyster

shells to heat, and then placing them into a crucible with sulphur, and again heating them. If the product, when cold, be put into a bottle, well stoppered, and exposed to sunshine for a few minutes, it will give out, when taken into a dark room, sufficient light to shew the hours on the dial-plate of a watch; and when the phosphorescence has ceased, it may be renewed at pleasure, merely by exposure to sunshine.

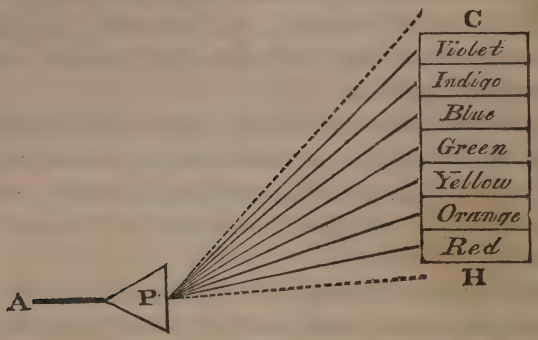
Temperature has considerable influence on phosphorescence. Heat increases it, while cold in general destroys it; and after it has ceased, it may be renewed by the application of heat, and many do not act in this way till it is applied.

Phosphorescence is altogether independent of the air, as it takes place even when the body is excluded from it; indeed a substance retains this property in proportion as the atmosphere is prevented from acting on it; from which it is evident, that it is not, as some have supposed, owing to combustion. It seems to be occasioned merely by the extrication of that light, which the objects had absorbed when exposed to it.

The absorption of light depends on the nature, particularly the colour, of the surface. The experiments of Franklin and of Davy, in which pieces of cloth, and of metal of different colours, were exposed to sunshine, have been already noticed, (page 84). From these it has been shown, that the darker the object the more is the absorbing power, and it is to this that some have ascribed the effect of surface in absorbing radiant heat; the light so easily taken in by black bodies, carrying along with it the calorific rays with which it is always mixed.

Sir Isaac Newton first made the discovery, that light coming from the sun is not simple, but composed of different rays, possessing various powers of refraction, as is proved by causing one to pass through a triangular piece of glass called a *prism*. For this, having darkened a room, a small hole is made in the shutter, and the prism, P, placed near it. If the ray,

A, when it passes through it, be made to fall on a sheet of white paper, a *spectrum*, H C, is produced, composed of *seven* distinct colours, *red*, *orange*, *yellow*, *green*, *blue*, *indigo*, *violet*. This separation of the rays is produced by



the difference in their refrangibility. Thus, the red is least refracted; it is therefore least bent from the straight line, and is consequently lowest in the spectrum; the others are situated in the order of their powers of refraction; the violet being most so, is at the top. That light is composed of these different rays, is also proved by taking a quantity of the colours, in due proportion, and mixing them, by which white is produced; or if the rays, instead of being thrown on paper, so as to form a spectrum, be made, after separation, to pass through a lens, they are collected into a focus, and white light is produced.

Any number of refractions or reflections, does not alter the permanency of these rays. Thus, if any one of them be made to pass through another prism, it still continues of the same colour.

Herschell has shown (Phil. Trans. 1800,) that the rays of which the spectrum is composed, have different powers of illumination. Thus, if a small object is placed at either end, it is seen indistinctly, but if brought towards the centre, it becomes much more distinct, the greatest illuminating power being between the bright yellow and the pale green.

These rays have also different relations with respect to bodies. It has been already said, that light passes

through transparent, but is retained by opake bodies. Several retain some of the prismatic rays, while they transmit or reflect others, and on this depends their appearance and colour. One which transmits all the rays is colourless, while one which absorbs them is black. When a body retains all the rays but one, which it either transmits or reflects, it is of the colour of the reflected or transmitted ray. Thus, red glass transmits all the rays but the red one; blue cloth absorbs all but the blue one, which it reflects.

The sun's rays are the principal source, not only of light, but also of *heat* to this globe. It has been already mentioned, that when light strikes a polished body, it is reflected, or a transparent one, it is transmitted; and if the former be concave, or the latter convex on both sides, the reflected or transmitted rays are collected into a focus; at this point an intense *heat* is excited, provided the mirror or lens be of sufficient size.

The rays of which the spectrum is composed, possess very different heating powers, as has been proved by the experiments of Herschell.—He found, that when the bulb of a delicate thermometer was exposed to the violet ray for 10 minutes, it rose only 2 degrees, in the green in the same time $3\frac{1}{2}$, but in the red 7. It was found, however, that when the instrument was placed *beyond* the red ray at H, it actually rose higher than when in it; it was affected even at the distance of $1\frac{1}{2}$ inch from the end of the spectrum. When placed beyond the violet ray at C, it was not changed.

These experiments, afterwards confirmed by those of Sir H. Englefield, prove, that solar light is composed not only of a *luminous*, but also of a *heating* ray, and which has been found to be quite distinct from the former, possessing laws peculiar to itself; thus, they are less refrangible, hence they are placed *beneath* them in the spectrum. They can be reflected or transmitted, and collected into a focus, like the others, and hence the source of the heat produced by a lens, when the solar rays are allowed to pass through it, or by a metallic concave mirror, when they are reflected and concentrated. It has

been mentioned, that the different coloured rays of the spectrum have different heating powers ; this, it has been found, depends on an admixture of the heating rays. Thus, the red, which is nearest the latter, has the greatest, and the violet, which is at the greatest distance, has the least effect on a thermometer ; the effect gradually diminishing, as we proceed from one end to the other.

The rays of the sun, besides imparting heat and light, also effect very powerful *chemical changes*, a familiar instance of which is, the blackening of indelible or marking ink, the traces of which are at first invisible, but soon become black on exposure to sunshine, or even to day-light. The prismatic rays have different powers in inducing these changes. When, for instance, a spectrum is produced, and a line is drawn with the ink, in the different rays, and exposed to sunshine, that in the violet ray is soonest blackened.

The discovery of a heating ray beyond the luminous ones in the spectrum, naturally suggested the idea of the chemical effects being produced in a similar manner. This first occurred to Ritter, who placed a compound of silver, (the white chlorid,) beyond the violet ray in the spectrum, and he found not only that it was blackened, but that it became sooner so than when in the violet ray itself. When put beyond the red one, no change took place. Hence he concluded, that the solar ray likewise contains one which produces chemical changes quite distinct from those that are luminous and calorific.—These experiments, and consequently the conclusions drawn from them, have been confirmed by Wollaston, who found that chemical actions are produced by rays quite independent of the colorific and calorific.

It has been already mentioned, that the different prismatic rays have different powers in effecting chemical changes. This, it has also been proved by experiment, depends on an admixture of the chemical. Ritter asserts, that he succeeded in producing a spectrum of the light-giving rays, which had no power whatever in blackening the chlorid of silver, which he accomplished by causing them to pass through a series of prisms, by which, owing

to the difference in their refrangibility, they were separated.

Such is the idea in general entertained concerning the constitution of solar light,—that it is composed of three distinct rays, each having its own properties,—the light-giving, or luminous; the heat-causing, or calorific; and the chemically-acting ray,—which may be separated entirely from each other.

Experiments have also been lately performed, which confirm the opinion sometime ago advanced, that light possesses the power of magnetizing needles. Morichini first asserted, that when a piece of iron was kept in the violet ray, it became slightly magnetic, but others were inclined to suppose that the effect might be owing to other causes than that to which it was ascribed. Mrs Somerville has however proved, by a numerous set of experiments, an account of which has been read before the Royal Society, that Morichini was correct. She has found, that by exposing sewing needles to the violet ray for about two hours, they become magnetic, and by concentrating the rays by a lens, the effect was more quickly produced. The indigo ray has likewise the same power, and so has also the blue and green, though to a less extent; but the yellow, orange, and red, seem to want it. A similar effect was produced on needles by exposing them to the solar rays, concentrated by lenses of the colour of those which in the previous trials were found to possess the magnetizing power.

Philosophers are by no means agreed with respect to the relation which light and heat bear to one another. Some suppose that they are two distinct agents, occasionally found together, but not at all connected. Others, on the contrary, imagine, that they are but modifications of the same power, and that the one may be converted to the other. Those who espouse the former opinion, found the truth of it on the fact, that the properties of light are quite different from those of heat; while, on the other hand, light being the source of heat, and bodies emitting light, when strongly heated, and the frequent

disengagements of these agents together, has given rise to the latter. Perhaps the strongest argument in favour of the former, is the total absence of any heating power in the rays of light, when separated from those of heat. Besides, the effects produced by these agents are quite different. On the other hand, however, it must be admitted, that there are experiments which seem strong in favour of the latter. Delaroche found (An. of Phil. ii. 100.) that the heat radiated from a warm object, passes through glass with great difficulty when the temperature is low, but as it is raised it penetrates more easily; the facility with which it passes increasing with the temperature. From this, some have supposed that heat may be converted into light, as it is well known that the rays of the latter pass through glass without interruption.

The influence of light over the objects of nature is very great. By its rays entering the eye, vision is produced. The effects on the vegetable world are not less striking. Plants always extend their branches to the light, and many of them follow the course of the sun. When completely excluded from its influence, they become feeble, insipid, and colourless; but, when again exposed to it, they regain their strength, and assume their former appearance. On this depends the operation of *blanching*, which is merely excluding the plant, suppose celery, from light, by covering it with earth, by which its colour is banished, and its flavour altered.—The effects of light on inanimate objects are numerous. One of these has been mentioned,—the blackening of marking ink, which is owing to the decomposition of the salt of silver it contains. Changes of a similar nature are produced on other bodies, which will be afterwards mentioned.

Following the order in which the different subjects to be treated of have been enumerated, we ought next to consider Electricity and Galvanism; but to enable the reader to understand these, it is necessary that he be acquainted with the composition and qualities of the substances subjected to their influence, and which it must be supposed he has not yet acquired. It has been thought proper, therefore, to defer the consideration of them, till the properties of inorganic bodies have been described. Should he wish, and it may perhaps be proper that he ought, to have a general knowledge of them before he proceeds farther, the article on Electricity, and that on Galvanism, so far as the discussion of its chemical changes, may be cursorily glanced over, and by which he will be enabled to know how they are applied as chemical agents.

SECTION III.

ATTRACTION.

The objects of the material system are constantly under the influence of a power, by which they are drawn towards one another, and indeed, would actually come into contact, were they not prevented by the operation of other agents. Thus the heavenly bodies are retained in their situations, and regulated in their movements, and objects of inferior notice are made to approach the earth. This power, to which the name of Attraction has been given, acts not only on the mass, but also on the parts of which bodies are composed.

It is universally allowed, that matter is made up of particles, or atoms, as they are called, and which are inconceivably minute. Thus, in reducing a piece of marble to powder, each part still continues a piece of marble, having the characteristic features of the mass itself; but this division is far short of what we are able to accomplish by other means. Thus, if a grain of green vitriol be dissolved in 100,000 of water, by the application of a proper test, as prussiate of potash, it can easily be detected, and shewn to exist in solution in every drop. But a drop of water can be divided into smaller portions, so that if we suppose it divisible into 100 parts, the grain of salt must have been composed of at least 10,000,000 of particles.

The particles of matter have been divided into *Integrant* and *Elementary*. The former are those into which a body can be divided, and which have the same

properties as the body itself. Thus, in the experiments mentioned, the marble and the salt of iron were separated into integrant parts. Of course, in all simple substances the atoms are integrant, but simples often unite to form compounds, so that the particles, into which these can be reduced, can be made to undergo a still farther separation into their elementary parts. Thus, if water, which contains two ingredients, be passed over red hot iron, one of them unites with the metal, and the other is liberated in the form of gas, so that its integrant are thus separated into elementary particles. In simples, it has been already said, that the atoms are all integrant; in compounds, on the contrary, they are both integrant and elementary.

In considering Attraction, it must be viewed as acting either on the mass, or on the atoms; and in the latter case also, whether these are elementary or integrant, because the results vary according as bodies are simple or compound. When it operates on the mass, it exerts its influence at sensible and often immense distances; whereas when the particles are acted on, it is necessary that the objects be in apparent contact. This has given rise to the division of attraction into the *remote* and *contiguous*, the former consisting of those of *gravitation*, *electricity*, and *magnetism;* the latter of *cohesion*, *adhesion*, and *affinity*, or *chemical attraction.*

By gravitation is meant that power, by which the objects of the universe are drawn towards each other; the bodies of the planetary system being by it regulated in their movements. Newton ascertained that the force of this increases directly with the quantity of matter, and decreases as the squares of the distance. The magnetic and electric attractions are illustrated, the former by a loadstone drawing to it a piece of iron, the latter by amber, when rubbed, attracting light objects. These also act on the mass, and at sensible distances.

The contiguous attractions operate on the atoms, and when they are apparently in contact; the cohesive causing those of the same kind of matter to unite, and form an

object, the characteristic features of which are the same as those of the particles themselves; the adhesive uniting the atoms of different bodies, but without altering their properties; whereas the chemical, in effecting a union, is accompanied with a change of qualities. Of the intimate nature of these attractions we are completely ignorant. Some have supposed that they depend on the same cause, but modified by external circumstances, and thus producing their diversified operations; while others imagine they are altogether different, and when we consider what opposite effects are produced by their operation, we are almost naturally led to adopt this opinion. The illustration of the phenomena occasioned by the remote attractions, is the province of mechanical philosophy. To the chemist belongs the consideration of the other class, which, we shall find, presents a wide and an interesting field of inquiry. In treating of contiguous attractions, we have first to consider the cohesive, then the adhesive, and lastly, the chemical, or affinity.

Cohesive Attraction.

Cohesive attraction is that power which causes the particles of the *same body* to approach and unite; and when united, it retains them in that state. Thus, if two globules of quicksilver on a smooth table be brought near each other, they run together, and the particles thus joined, will remain so unless separated by some foreign power.

Cohesive attraction exerts different forces in bodies, and even in the same body at different times. It is strongest in solids; thus, in attempting to break a bar of iron, all our efforts are unavailing, the particles are kept together so powerfully by cohesion. In fluids it is not so great; the slightest force is able to separate them, and little or no resistance is offered to their assuming new arrangements. That there is a cohesion, however, among the particles of bodies in this state, is evident from the globular form of a drop of any fluid. If, for instance, a glass

rod be dipt into water, on removing it, the water adhering to it assumes a globular form, the particles being kept together by cohesion. In aeriform substances, on the contrary, this power is entirely overcome; so that there is no cohesion among their particles, which, instead of attracting, repel each other. They are made to approach by pressure, and as it is removed, they again recede.

Cohesive attraction is also different in the same body at different times, which is occasioned by the powers that tend to weaken it, as caloric and chemical attraction. When a solid is heated it is enlarged, by which the cohesion is so far overcome; but if we still continue the addition, it becomes fluid, the cohesion being still farther weakened; indeed so much so, that the particles move freely on each other, and present little or no resistance to their separation. By continuing the application of the heat, the cohesion is completely destroyed, and the body then assumes the aeriform state. Cohesion is also overcome by chemical attraction, as is well illustrated in instances of solution, and also in the action of acid on metals. Thus, if a piece of zinc, between the particles of which the cohesion is very powerful, be put into diluted oil of vitriol, it is soon dissolved.

When caloric and chemical attraction operate at the same time, cohesion is more easily overcome, and in many cases it is necessary to call in the aid of both before it can be completely destroyed.

When the powers which have overcome cohesion are withdrawn, it again begins to operate, and the substance assumes its original form. Thus many aeriform fluids, by depriving them of part of their caloric, become liquid, and liquids, by a still farther reduction of temperature, are congealed. By withdrawing also the chemical attraction which had overcome the cohesion, the substance becomes fluid or solid. Thus many bodies, when held in solution by water or acid, may be separated by chemical attraction. If, for instance, a piece of zinc be put into a solution of sugar of lead, and in which the metal is held dissolved by the acid of vinegar, lead is de-

posited in its metallic state. When cohesion operates after the removal of those causes, the particles unite sometimes indiscriminately, and form irregular masses; at other times, in assuming their original state, they arrange themselves in a particular manner, and objects of a regular shape are produced. When it is powerful and operates suddenly, the body assumes an irregular form; but if the causes which have overcome it be gradually withdrawn, the particles arrange themselves in a particular way, and regularly shaped masses, having plain surfaces, and angles peculiar to themselves, are formed. The substances procured in this way are called *crystals*, and the process is termed *crystallization*. A short account of the different circumstances connected with it is necessary.

Crystallization may be produced in two ways; either by the consolidation of a body made fluid by heat, or by the diminution of the solvent power of a liquid which has dissolved a solid. When a substance has been fused, and is allowed to cool slowly, and without being disturbed, crystals may be formed. To secure the success of the process, the vessel ought to be surrounded by a bad conductor, as sand, fine ashes, or saw-dust, and after the sides and upper part have congealed, a hole must be made in the surface, and the unconsolidated matter poured out, by which the inside will be found to present a beautiful congeries of well-formed crystals. In this way, those of sulphur may be easily procured.

The second method of producing crystallization, viz. solution, is by far the most common; the crystals are much larger, and better formed than those obtained by the other process. The solvent most commonly employed is water. Crystallization by solution is conducted in two ways; either by evaporation, or by diminishing the solvent power of the fluid by a reduction of temperature. The evaporation may be carried on spontaneously, or by the aid of heat. When the crystals are required to be large, recourse is commonly had to the former, as the fluid is more gradually carried off by it than by the latter. If one or two well-formed crystals of the substance

in solution, be put in during the evaporation, the success of the process is more certain.

Most bodies are more soluble in hot than in cold water. If, therefore, a saturated solution, or which is better, one nearly so at a boiling heat, be allowed to cool slowly, which is done by surrounding the vessel with a bad conductor, the part that the water cannot keep dissolved, when it cools, is deposited, and the deposition going on gradually, crystals are formed, and the greater the quantity of the solution, and the more slowly it cools, the better.

In both of these methods, the fluid left after a crop of crystals has been obtained, is one saturated at a natural temperature, so that, by boiling off a part to make it saturated, another crop may be got, or it may be made to yield crystals, by evaporating slowly, either by heat or spontaneously.

The access of air seems necessary for crystallization, at least it has an important influence over it. Thus, if we have a saturated solution of glauber salt, at a boiling heat, and withdraw the air from the vessel, there is no deposition when it cools, but on the admission of it, crystallization commences. This is easily shown by boiling in a flask a solution of the salt, till it becomes saturated, by which the whole of the air is expelled. When in this state cork it tightly, and then surround it by sawdust, and as the temperature falls there will be a vacuum by the condensation of the vapour, but the whole continues fluid. On removing the cork, the crystallizing process instantly commences, and all that part of the salt, which the fluid ought to have deposited as its temperature fell, becomes solid. Though air is necessary for this process, yet it seems to act merely by its pressure, probably bringing the particles near enough to enable them to unite and form a solid; an idea which is strengthened by the fact, that though a fluid is relieved of the pressure of the atmosphere, yet, if subjected to that of a column of mercury, crystallization takes place.

Crystallization may likewise be prevented, by causing

the fluid to cool very gradually, and without the slightest agitation. Thus, if a saturated solution of glauber salt in a flask, be surrounded by a bad conductor, a cork being placed into the mouth of it, to prevent the admission of objects floating in the atmosphere, it will allow its temperature to fall many degrees below that at which it ought to have deposited crystals, without any being formed. The moment, however, that a piece of the salt is thrown in, crystallization commences, and the whole of that which ought to have been consolidated as the temperature fell, is separated. This is supposed to operate by the agitation occasioned by the introduction of the salt; for it is well known, that throwing in any other body, or even shaking the vessel, causes the crystallization of a fluid under similar circumstances.

A nucleus in the fluid also favours the crystallizing process; hence the introduction of a few well-formed crystals into a solution undergoing evaporation, causes the formation of others of a regular shape.

During crystallization heat is evolved. When the crystals are slowly formed, its extrication is gradual, and scarcely perceptible; but when they are quickly deposited, it is sufficient to affect a thermometer, and this is well illustrated in those instances, in which the temperature has fallen below that at which crystals ought to have been formed. Thus, if a warm saturated solution of glauber salt be surrounded by saw-dust, and two or three hours afterwards a thermometer be put into it, the crystallizing process does not go on as the fluid cools. But on causing it to take place, by throwing in a crystal, the thermometer is instantly affected. Of course, the rise of temperature is accounted for, either by the disengagement of latent heat, or by the change in capacity, as has been already illustrated when treating of fluidity.

Two or more solids are often contained in the same solution, but they can be easily separated by crystallization; because, as salts require different quantities of water to dissolve them, if a fluid of this kind be evaporated, they will be deposited in the order of their solubility, that

which is least soluble being first separated; hence on making the solution saturated at a boiling temperature, it will on cooling deposit crystals, and by removing these, the others may be obtained by farther evaporation.

Crystals procured by fusion, differ from those got by solution, as they in general contain some of the solvent; and as that commonly employed is water, what they retain is called *water of crystallization.* In some cases the quantity is small, but in others it is large, as in common soda, in which it actually amounts to about 2-3ds of the weight of the crystals. This difference in the quantity of water gives them particular properties. Thus, those which have but little of it when heated, undergo what is called *decrepitation;* their particles are separated with a crackling noise, owing to the sudden conversion of the water into vapour, the expansive force of which bursts asunder the parts of the salt; sea salt affords an instance of this. Those, on the other hand, which contain much water of crystallization, when exposed to heat, undergo what is called *watery fusion,* which is the solution of the salt in the water; and that it is so is known by continuing the heat, by which the matter becomes solid, and requires after this a higher temperature for its liquefaction. Glauber salt affords an instance of this.

When speaking of crystals, terms are employed to denote particular changes that have taken place during their formation. A crystal is said to be *bevelled,* when the sides or terminal planes are so altered, that instead of these, there are two converging like the roof of a house. It is *truncated* when the edges or angles are cut off, so as to form a plane, where there should have been an edge or angle. It is *acuminated,* when, instead of the angles or terminal planes, there are three or more faces converging so as to form a point or pyramid.

When crystals are examined, they present a variety of symmetric forms, but each substance has a figure peculiar to itself, and within a certain limit this seldom varies; thus, sea salt crystallizes in cubes, glauber salt in oblique rhombic prisms. A considerable variety, however,

often occurs in the same body; but in these cases each presents one invariable figure as its appropriate one, from which all the diversities have sprung. This is called the *primitive*, and the others formed from it the *secondary* or *derivative* form. The idea that crystals contain a particular form, different from that of the crystal itself, but from which its figure may be derived, seems to have originated with Bergman, and which was adopted by Romé de l'Isle, as the basis of his system of crystallography. In order to discover the forms from which all the secondary figures may be derived, he entered into a geometrical investigation of what he conceived to be the different primitive ones, and to account for the variety of crystals, he imagined that some circumstance may occur during their formation, which may not act equally on all sides, and consequently a redundance or deficiency may be the result, and these taking place on the edges, faces, or angles, an immense number of differently formed crystals may be procured from the same primitive figure.

These speculations of Bergman, and De l'Isle, were afterwards confirmed by the experiments of Hauy, who has shown that crystals do contain a primitive form; that, however much those of any body may vary, they contain a central form or nucleus, which is the same in all the varieties. These, he says, may be discovered by a mechanical analysis or dissection of the crystal. Indeed he was led to this discovery by observing, that in breaking a six-sided prism of carbonate of lime, it did not split off parallel to the sides, but in an oblique direction; each fracture caused by the blow presenting a smooth surface, till at last he procured a body of a rhomboidal form, which by repeated blows was diminished, but not in the least altered in its figure. On treating other varieties of crystals of the same body in a similar manner, he found, that however different in shape, it always yielded a rhomb, and hence this was considered the primitive form. The primitive forms of Hauy are the *parallelipepidon*, which includes the cube, the rhomb, and all solids having six faces parallel two by two; the

tetrahedron; the *octohedron;* the *regular hexahedral prism;* the *dodecahedron* with equal and similar *rhomboidal planes;* and the *dodecahedron* with *triangular planes.* From these, Hauy says, all the variety of crystals may be procured, the diversity being occasioned by a decrease in the number of particles, during the formation of the secondary on the primitive form; and if we suppose that this may take place either on the edges or angles, and sometimes on all of these, and at others only on some of them, and occasionally varying from one edge or angle to another, it is easy to conceive, that on the same primitive figure an immense variety of differently shaped crystals may be produced.—For a full illustration of this subject, which the limits of this work do not admit, the reader is referred to Philip's Introduction to Mineralogy, and Brooke's Introduction to Crystallography.

Adhesive Attraction.

Adhesive attraction is distinguished from the cohesive, by its causing *different bodies* to adhere. Thus, if a plate of glass be dipt in water, part of the fluid attaches itself to it; or when a liquid is contained in a glass jar, the edges are observed to be higher than the surface. If a piece of sponge also, or of sugar, be partly immersed in water, the whole soon becomes moist; and when a tube with a very fine bore is put into it, the fluid is higher in the inside than on the outside. These are all caused by adhesive attraction. In the last instance, it is commonly called *Capillary attraction,* from its making fluids rise in capillary tubes; and the same is also said to be the case with the sponge and sugar, the fluid rising through them by capillary attraction.

Chemical Attraction.

Chemical attraction is that power by which the particles of *dissimilar objects,* when brought into contact, are made to unite, forming a compound, having properties different from those of its ingredients. It is distinguished from gravitation by its taking place at *no sensible dis-*

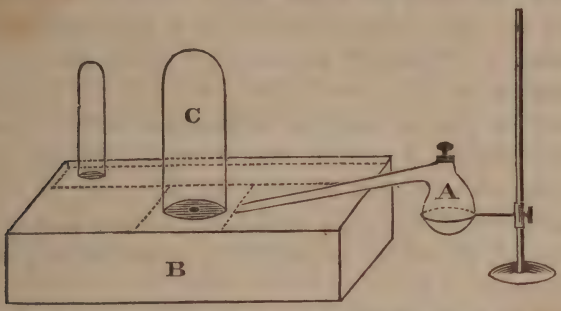
tance, and among the atoms of bodies. Cohesion is exerted among the particles of the *same* body, and when these are united, the properties are not different from what they were before the union. The term *Affinity*, has generally been employed to denote this power, but this term, it must be remarked, is often used in a double acceptation; to denote both the power, by which the particles of different bodies are made to unite, and also the changes produced by its operation; in the one meaning the cause, in the other the effect.

When substances, between which there is an attraction, are presented to each other, and a change ensues, it is said that a *Chemical Action* has taken place. It is necessary, therefore, to draw the distinction between the terms Chemical Attraction, and Chemical Action. By the latter, is meant the change that follows the application of bodies to one another, and by which their properties are altered. By the former, is to be understood the power which has induced this change.

It has been already mentioned, that the term affinity has been used to denote both the cause and the effect of that power by which bodies are made to combine, and form new compounds. It will be better, therefore, to employ Affinity, and Chemical Attraction, to express the former, and Chemical Action the latter.

Chemical action does not always take place when substances are mixed. Thus, if oil and water be shaken together, they do not act; but if, instead of using water, lime-water be employed, an action ensues, the particles of the oil unite with those of the lime, and form a new compound. When substances which are simple are made to act, this is the only result. It is called *Combination* or *Synthesis*, (συντίθημι, to put together,) and when a compound is formed in this way, it is said to be procured by Synthesis. Substances are, however, frequently composed of two or more ingredients, and when an action takes place between them, it is in general much more complicated. When, for instance, a body of one ingredient A, is added to a compound BC, A may unite with B, form AB, while C, the other ingredient, is

set free. Thus, when chalk, which consists of lime and a gas called carbonic acid, is placed in a retort A, and muriatic acid poured on it, the muriatic acid unites with the lime, from which the carbonic acid is separated, and may be collected. The compound of the acid and lime remains in the retort; the gas is collected in the jar C,



placed on a water-trough B. In this instance, we have the ingredients B and C separated, and BC is therefore said to be *decomposed.* This, then, in chemical language, is called *decomposition* or *analysis*, (αναλυω, to *separate.*) But, in this case, there is also combination. A has combined with B, so that there is both combination and decomposition. When bodies are simple, combination is the only result; but when they are compound, there may be both combination and decomposition.

The difference between the integrant and elementary atoms has been already stated. By the former is meant, the smallest particle of a body, and which has the same properties as the body itself. The elementary, on the contrary, are those of which the integrant are composed, these having properties different from each other, and from those of the particles which they form by their union. The latter are united by chemical attraction, the former by cohesion. When, then, an action ensues on the application of bodies to each other, the attraction is exerted at one time among the integrant particles, as when two, each composed of two ingredients, unite to form a new compound, of course containing all the four. At other times it operates among the elementary, as when decomposition ensues; thus, in the instance mentioned, some of

the elementary particles of the marble have combined with those of the acid, while the others were set free in the form of gas.

That chemical attraction may operate, and produce chemical action, it is necessary that the substances be brought as near as possible. Many bodies, when mixed, do not act, till means are employed to approximate their particles, as friction or percussion. Thus, when flowers of sulphur are mixed with the powder of the salt called chlorate of potass, there is no chemical action; but on rubbing them in a mortar, they instantly explode. Here, it is supposed that the friction has operated, in a great measure, by bringing the particles of the one near enough to those of the other, to enable the attraction to produce its effects.

It is in general also necessary, that one or both of the bodies be fluid. Thus, when nitre and flowers of sulphur are mixed, there is no action; but if the former be melted, and the latter thrown into it, it is instantly kindled, and burns with a bright white flame, giving off very noxious fumes. Though in general one or both of the substances must be fluid, yet this is not always necessary. Thus, in the former instance of the sulphur and salt, both are solid, yet there is an action when they are rubbed.

In the experiment of sulphur and nitre, the fluidity was occasioned by heat. In others, it is effected by water, which dissolves one or both bodies. Thus, when potashes are mixed with the substance called oxalic acid, there is no action; but on adding a little water, it instantly commences, and is accompanied with the disengagement of an aeriform fluid, which is one of the ingredients of the former.

Caloric in general favours the operation of chemical attraction. Many bodies, when mixed at a natural temperature, remain in that state; but when heat is applied, an action commences. On the contrary, cold or the abstraction of heat in general retards it, of which we have a good instance on mixing aquafortis with spirit of wine. When the acid, previously diluted with about twice its

bulk of water, is put into a flask, with an equal quantity of alcohol, there is no action, but on applying a slight heat, it commences, and is accompanied with the disengagement of gas, which may be kindled on the approach of flame. On putting the vessel into cold water, the action instantly ceases, the flame being extinguished, and on again applying heat, it commences.

By the operation then of attraction, bodies are made to unite, and form new compounds. When this is the case, *an alteration of properties is the result;* the compound no longer possessing those of its ingredients. Hence we find the form, the taste, or the smell, altered. The chemical properties have likewise undergone a change, of which we have a good instance, in the result of the action of an acid and an alkali. The distinguishing feature of the former, is making a vegetable colour red; hence, if we add a few drops of sulphuric acid, or oil of vitriol, as it is commonly called, to the blue infusion obtained by steeping the leaves of red cabbage in water, the colour is instantly reddened. The distinguishing character of an alkali, is making the vegetable colours green; hence, when a few drops of soda are added to the same solution, it becomes green. Oil of vitriol and soda have a very strong attraction for each other. When mixed, they unite, and form a new compound, and which has no effect whatever on vegetable colours. If, then, the infusion to which the acid was added, be mixed with that containing the soda, in proper proportions, the acid and the alkali combine, and the original colour returns, because the compound formed does not act on the colouring matter. In this case, also, the corrosive qualities of both are destroyed; in fact, Glauber salt is formed.

It must not, however, be supposed, that the properties are in every case destroyed. Thus, when sugar or salt is dissolved in water, which is a case of chemical action, the qualities are little altered. In most, however, there is a total change, and when it is so, the bodies are said to have *saturated* or *neutralized* each other.

Changes produced by Chemical Attraction.

Of the alterations produced, none is more striking than a change of form. This sometimes takes place in one, occasionally in both substances; we have often two fluids becoming solid, as when diluted oil of vitriol is mixed with a solution of the substance called muriate of lime. On the contrary, two solids may become fluid. Thus, when ice and sea salt are mixed, they act on each other, and are very soon liquefied. It frequently happens that a gas, or aeriform body, is given off from a solid or fluid; as when chalk, or a solution of potashes, is thrown into muriatic acid. Perhaps the most common change is when a solid and a fluid act, and the former becomes liquid. In this case, it is generally supposed that the fluid is the active agent, that it is the cause of the solid assuming the same form, it is said, therefore, to *dissolve* it, and the process is called *solution*, the fluid itself being termed a *solvent*, (words derived from *solvo*, to *loosen.*) The fluid is also frequently called a menstruum, a term given by the ancients, and derived from *mensis*, a *month*, many of their processes requiring a considerable time to complete them. Thus, when a salt is put into water, or alcohol, a watery or alcoholic solution is formed; or, as it is sometimes called, a solution in a watery or alcoholic menstruum.

When two fluids act, and a solid is formed, which falls to the bottom, *precipitation* is said to take place; and the solid is called a precipitate, (*precipito*, to *throw down.*) Thus, when a solution of sugar of lead is mixed with that of Glauber salt, a white powder is precipitated. When, on the contrary, an aeriform body is given off, either from fluids or solids, or by the action of a fluid and a solid, *effervescence* is said to occur, and the bodies are said to *effervesce*, (*effervesco*, to *boil over.*) Thus, when potashes, or a piece of chalk, is thrown into muriatic acid, there is an effervescence, or the escape of gas.

Another very common change accompanying chemical action is, an *alteration in the bulk* of the substances. When

this happens, they in general occupy less space than before, though in some instances they are enlarged. It is well known, that when a very strong spirit is mixed with water, there is a condensation. Thus, if 50 gallons of each be used, there are only about 97 of the mixture. The condensation accompanying chemical action is well illustrated, also, by oil of vitriol and water. If 50 measures of acid be mixed with 50 of water, they enter into union, and give considerably less than 100 measures. In this case, the condensation is at first slight, because, owing to the action, there is a disengagement of heat, which causes expansion; but if the mixture be kept for a few hours, to allow it to regain its original temperature, it will be found to occupy much less space than the substances separately, there being only about 93 measures. On the contrary, instead of an increase, there is a diminution of density. Thus, when some of the metals unite, they form compounds called alloys, the density of which is less than the mean of those of the metals when separate.

The next, and most remarkable occurrence during chemical action is, a *change of temperature*, or, as it is usually called, a generation of heat or cold. The alteration is in many cases considerable, in others it is less striking; in almost every instance, however, some change does take place; indeed, nearly all the means of producing heat and cold are derived from this source.

The rise of temperature may be shewn, by pouring oil of vitriol on recently burned lime; they enter into union, and heat is given out, sufficient to drive off part of the acid in vapour. In other instances in which fluids act with each other, there is a disengagement of heat. Thus, when equal measures of oil of vitriol and water are mixed, heat is evolved sufficient to cause water to boil, or even to set fire to some inflammables. If a small piece of phosphorus, in tow, be put on the glass in which the mixture is made, the moment the fluids are stirred to cause them to combine, it is kindled.

The instances mentioned are cases of chemical action between solids and fluids. The evolution of heat, by

combustion, affords a good example of the rise of temperature during the action of these with an aeriform body; this process depending on the union of the inflammable with a part of the air of the atmosphere.

Instead of the disengagement of heat, we have frequently the production of cold, as when solids are dissolved, or when they act on each other, and both become liquid. Thus, when ice and sea salt are mixed, there is an immediate chemical action; both become fluid, and cold is generated. How the rise and fall of temperature in these cases is occasioned, has been already fully illustrated under Fluidity and Evaporation, and also under Sources of Heat and Cold.

Of the Powers which exert an influence over Attraction.

Chemical action varies at different times, even among the same bodies; which has given rise to the idea, that attraction is influenced by particular circumstances, and that it is by the operation of these, and not by any difference in the attraction itself, that the results are so different. Berthollet has paid particular attention to this subject; indeed, it is to him that we are indebted for almost all we know concerning it. His illustrations of it are to be found in his Essay on Affinity, and in his Chemical Statics.

In considering the circumstances which affect affinity, we must view it either as producing only combination, or both combination and decomposition. Those which have an influence over attraction, producing combination, are *cohesion*, *gravity*, *condensation*, *elasticity*, and *temperature*. Those affecting the attraction among compounds, producing decomposition, are the same, with *quantity*, or a *difference in the proportions*.

The first of the circumstances that affect the operation of affinity is *cohesion*, which is strongest in solids, and it is in these only that it has any influence. When two substances, between which there is a chemical attraction, are mixed, it is evident that the result must depend

greatly on the state of cohesion. If the affinity be strong, it overcomes the cohesion; but if weak, it is overpowered by it, and little or no action ensues. Hence the cause of chemical action occurring so rarely between solids; the particles of the two bodies are not only too far removed from one another, but that force which keeps those of each together, offers so strong a resistance to their separation, that the chemical attraction cannot overcome it. With respect to a solid and fluid, the action depends also entirely on the state of cohesion of the former. Thus, when a *lump* of iron is put into aquafortis, previously mixed with its own bulk of water, there is scarcely any action; but if this be removed, and iron *filings* thrown in, it instantly becomes violent, and they are very soon dissolved. In the former, the cohesion among the particles of the iron was so powerful, that the attraction between it and the acid, even though strong, could not overcome it. In the latter, the cohesion being in a great measure destroyed, it easily produced its effects. It is true, in this instance, that the reduction of the metal to powder must cause a greater surface to be presented to the acid, and thus the action may be promoted; but the principal cause of the successful operation of the attraction, is the destruction of the cohesion, which the affinity must have overcome, before it could have produced its effects.

Since cohesion exerts so great an influence over affinity, it is necessary, when solids are used, to have them in powder, or to melt them. Accordingly, when we wish to dissolve a body quickly, we reduce it to powder, and the finer it is, the more rapid the solution.

It is often said, that as we diminish cohesion, we increase the affinity, which, however, it must be evident, is incorrect. Though the effect produced in the instance given is different, the attraction is not in the smallest degree varied. It is the action, not the attraction, that is altered by the change in the state of cohesion.

Cohesion, it has been supposed by some, acts in another way. Thus, if two bodies, between which there is an

attraction, be mixed, and if, when united, the cohesion of the particles is powerful, it is said that the affinity more easily produces its effects. Thus, if sulphuric acid be added to a solution of baryta, a white powder, sulphate of baryta, is formed, between the particles of which there is a strong cohesion, and which, it is imagined, favours the union. It is absurd, however, to suppose that this power can operate in the smallest degree in causing combination; because till they are united there is no cohesion, consequently, it does not begin to operate till after the chemical attraction has brought about the union.

Though cohesion can have no influence over attraction in the manner supposed, it may, however, operate by removing the product from the sphere of action,—as when a compound formed by the union of others is precipitated, and hence prevented from being acted on by any of the substances which may be in excess.

The *weight* of bodies also affects attraction. Thus, if we have a fluid, suppose water, in a tall jar, and put into it a body of considerable weight, say a piece of blue vitriol, it instantly falls to the bottom, and remains there, and slowly unites with the water. A solution is thus formed, which, by containing the salt, is of greater weight than the water above it; it therefore also continues below, surrounds the remainder of the solid, and cuts it off from the action of the fluid that has not entered into union with it. The blue vitriol will therefore continue days, or even weeks, before the whole of it is dissolved. Even after it is dissolved, the solution, from its great weight, continues a long time without mixing with the water; thus giving an instance of difference in the weight of *fluids* retarding their union. Of this we have also a good example in oil of vitriol and water; if the vitriol be put into a glass, and the other poured cautiously over it, they unite very slowly, the acid being of great weight, and remaining below. In cases, then, in which there is a great difference between the weights of the substances, we must have recourse to constant agitation, to favour

the operation of the attraction existing between them; indeed, it is absolutely necessary for it to produce its effects.

Elasticity is another of the powers modifying the result of attraction. By elasticity is here meant the tendency which the particles of substances have to separate from one another, as in aeriform bodies; and it is only in these that this power has any influence. It has been already proved, that as cohesion is diminished, chemical action takes place more easily. It may be expected, then, that substances in the aeriform state would act readily, either among themselves, or with other bodies, because in them the cohesion is destroyed. This, however, is not the case; the particles are too far removed to allow the attraction to bring them together. In those instances, also, in which an aeriform substance is absorbed by a fluid, it is well known that compression favours the union. Thus, in making soda water, the aeriform substance which causes the briskness is forced in by strong pressure, by which more of it is taken up, its particles being brought nearer each other, and to the surface of the water; the distance at which they were situated having prevented their combination.

Temperature has a very powerful influence over attraction; indeed, no agent is more frequently employed for inducing chemical action. Solids very rarely act with each other, but, on the application of heat, the attraction begins to operate. Thus, when flowers of sulphur and iron filings are mixed in about equal bulks, there is no action, but, on the application of heat, it soon commences, the mixture becomes red hot, and continues so for some time, even though removed from the fire,—shewing evidently, that a chemical action is going on. The promotion of the solution of solids in fluids by heat, is too well known to require any illustration. In many instances, there is no action between a solid or fluid and air, till heat is applied, of which combustion affords us a good example. Oil and coal are not inflamed till heated; but when their temperature is raised, they

begin to burn, and continue to do so, though the means by which their temperature is elevated be withdrawn. Now, in these cases, it is known, that there is an action between the inflammables and part of the air, by which the heat and light are disengaged. Aeriform bodies themselves very frequently do not act till heated. Thus, if coal gas be allowed to escape from a burner, it mixes with the air of the apartment, but there is no chemical action; if, however, a person take in a lighted candle into the room, the gas is instantly exploded,—the action between it and the air, which causes the explosion, having been occasioned by the heat.

The influence of temperature over attraction is to be ascribed, in a great measure, to its bringing into action some of the powers already treated of, particularly cohesion and elasticity. As we diminish the former, we favour the operation of attraction. Chemical action may therefore be induced by the diminution of the cohesion, for it is well known that heat overcomes this power. It is evident, however, that we may carry this too far; for, when we raise the temperature too much, we may weaken the cohesion to so great a degree, that the elasticity induced may retard, instead of promoting the action; that is, we may cause one or both substances to assume the aeriform state, and thus keep them from acting. In the instance of heat causing gaseous bodies to explode, it is supposed that it acts by the sudden compression of the particles; for, as it expands those immediately in contact with the flame, these must press on the adjoining ones, and thus they may be brought near enough to enable them to unite, the distance at which they were placed having proved a bar to their union.

On the contrary, cold sometimes favours the action. Thus, the union of two aeriform fluids, which do not act at a natural heat, may be effected by applying cold; and the cause of this seems to be the same as when they are compressed, the reduction of temperature contracting them, and thus bringing their particles near enough to enable them to enter into union.

The abstraction of caloric also favours the action of gases with liquids. Here, however, it is evident, that, as with the elevation, we may carry the reduction too far; for though we still continue to diminish the repulsion among the particles of the gas, yet we may increase the cohesion of the fluid, so far as to cause it to freeze, and thus put a stop to the union.

In the cases stated, it is evident that temperature exerts its influence over affinity, by increasing or diminishing the cohesion or elasticity of the substances employed. There are instances, however, in which it seems to exert some influence peculiar to itself. Thus, the solution of salts in water is greatly promoted by heat, as is also the union of the gases with some of the metals. It is true, that as the temperature is raised, the cohesion is diminished; but the diminution must be so trifling, that caloric seems to exert some peculiar influence in these particular cases.

The last of the powers having an influence over affinity is *Electricity*, and that modification of it called Galvanism; but, for the illustration of this part of the subject, *see Electricity and Galvanism.*

The preceding remarks apply to the chemical actions in which *combination* is the only result. We have now to view affinity in a different light. When a simple body, or one which acts as if it were simple, is added to a compound, and an action ensues, it is owing to the simple combining with one of the ingredients of the compound, and disengaging the other; hence *decomposition* also ensues, and the affinity by which this is brought about is likewise affected by foreign powers.

The powers which have been mentioned as having an influence over affinity, producing combination, are cohesion, specific gravity, elasticity, condensation, temperature, and electricity. These, with *quantity* or a *difference in the proportions*, modify affinity producing decomposition, in some instances promoting, in others retarding its operation.

Quantity, or a difference in the proportions, seems to produce a very great effect. Were chemical action

the result merely of attraction, the effects ought to be the same, whatever be the proportions. Thus, if a simple body be added to a compound, and the affinity between it and one of the ingredients be stronger than that between the substances already in union, the decomposition should be complete, that is, the body added should unite with one of the ingredients, to the complete exclusion of the other. This, however, is not always the case. If the quantity added be exactly that which would unite with the whole of the ingredient for which it has an affinity, the decomposition is imperfect. We must therefore add more of the simple; and even when this is done, there is not, at least in many cases, an entire decomposition, the ingredient of the compound, between which and the other substances there is an attraction, being divided between them. On the other hand, a strong attraction may be overcome by a weaker one, aided by quantity. Suppose we have a compound, and add a simple to it, between which and one of the ingredients of the former there is an affinity, but not so strong as that between the substances in union; if the simple be used in the proportion that it will combine with the ingredient for which it has an attraction, no decomposition ensues; but if used in excess, it is instantly effected. Thus, if we dissolve mercury in diluted nitric acid, and add a few drops of water to the solution, there is no decomposition; but if much of the latter be employed, the ingredients of the compound are instantly separated. Between the mercury and acid that has dissolved it, there is of course a certain force of attraction; the latter has also a tendency to enter into union with the water, but the affinity between them appears to be too weak to separate it from the other, and hence the necessity of calling in the aid of *quantity*, by which the decomposition is accomplished,—the acid and water unite, while the other ingredient is precipitated.

Cohesion is the next of the powers that modify affinity between compounds. The decomposition of a substance depends in a great measure on its cohesion. If it be

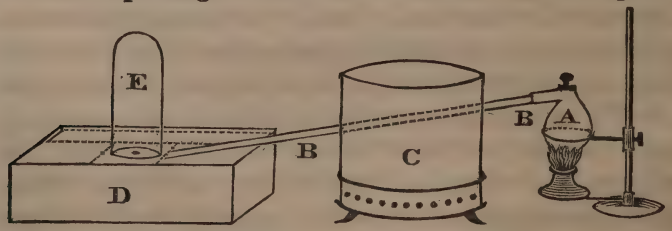
strong, it may prevent the chemical attraction from producing its effects, and the action may proceed slowly; whereas, if it be weakened, it may go on quickly. Thus, if muriatic acid be poured on a piece of carbonate of baryta, which is a compound of baryta and an aeriform body, the action is slow; but if the carbonate be reduced to powder, by which its cohesion is greatly overcome, and then mixed with the acid, there is a violent effervescence, the acid instantly combining with the baryta, and disengaging the other ingredient in its aeriform state. In those cases, then, in which we wish to effect the decomposition of a body quickly, it is necessary to reduce it to powder, or the cohesion may be overcome by dissolving it before it is mixed with the other that is to cause its decomposition.

Cohesion, it is imagined, aids decomposition in another way. In the instance given, it is that of the compound that retards the action; but it is supposed, that if the particles of the newly formed compound cohere strongly, the decomposition is more easily effected. Thus, when sulphate of soda is mixed with sugar of lead, the sulphuric acid of the former and the lead of the latter unite, and the compound is precipitated; so that there must be a cohesion among its particles, and which, it is supposed, favours the decomposition of the others. Though some lay great stress on the operation of cohesion in this way, it is difficult to conceive, nay perhaps absurd to suppose, that it can have any influence; for it must be kept in mind, that the cohesion is among the particles of the compound formed; now, till it is formed, there is no cohesion; so that it is bringing in the operation of a power not in existence.

Elasticity has also an influence over decomposition. If we have a compound containing an ingredient, which, when in its separate state, exists as a gas, the decomposition is more easily accomplished than if this substance, when pure, possessed some power of cohesion. Thus, if muriatic acid be poured on chalk, which contains a body that is gaseous when in its separate state, the acid

and the other ingredient of the chalk combine, while the gas is disengaged. It is supposed that the elasticity of the gaseous body favours the decomposition, by carrying it off from the sphere of action. If any means be employed to prevent the escape of the gas, the action does not go on. Thus, if the acid and chalk be brought into contact in a closed bottle, the action is at first slight, but very soon ceases; the moment, however, that the stopper is removed, it again commences.

Temperature is another of the powers that have an influence over decomposition. Many bodies, when united, remain so at a natural temperature; but on applying heat, there is an immediate decomposition. Thus chalk, which, it has been already remarked, is a compound of lime and a gaseous body, is easily decomposed in this way. If it be put into an iron tube, shut at one end, and having an empty bladder fixed to the other, on putting that, with the chalk, into a chauffer, the bladder will be very soon distended; owing to the aeriform matter escaping, the lime will remain in the tube. Here, then, the decomposition has been effected solely by heat. In other instances, it is necessary not only to raise the temperature, but to call in the aid of another body, otherwise we cannot decompose the compound. If iron be put into water, there is no decomposition, even though between it and one of the ingredients of the fluid there is a strong attraction; but if it be heated, there is an immediate action. Thus, on passing steam from a boiler, A, through an



iron tube, BB, it comes out at the opposite end, still in the state of steam; but if the tube be passed through a chauffer, C, and brought to a red heat, the steam is instantly decomposed, one of its ingredients unites with the

iron of the tube, the other comes out at the opposite end: and that it is a substance altogether different from the steam is evident, for if the mouth of the pipe be put into a water trough, D, an aeriform matter may be collected in the jar E. Had it been steam, it would have been condensed by the cold fluid; and that it is not air, is shewn by applying flame to it,—it is instantly kindled.

Electricity and galvanism have also an influence over affinity, producing decomposition; but for the illustration of this, *see Electricity and Galvanism.*

Force of Attraction among different Substances.

When a substance of one ingredient is added to another containing two, it occasionally happens that all the three unite, and form a new compound; that is, if A, a simple body, be added to BC, a compound, they may unite and form a substance ABC. It more frequently happens, however, that that added unites with one of the ingredients of the compound, while the other is set free. That is, if A be added to BC, A may unite with B, to form AB, and C is disengaged. Thus, potashes is a compound of an acid and an alkali, and between them there is a certain force of attraction. If it be placed in a retort, and oil of vitriol poured on it, it instantly combines with the alkali, and the acid, the other ingredient, is set free; it comes off in the form of gas, and may be collected in the jar. In this instance it is supposed, that the attraction between the oil of vitriol and the alkali, is more powerful than between the alkali and the acid from which it was disengaged; the acid and alkali are, therefore, separated, while the alkali and vitriol combine. This is called a case of *elective attraction*, because the vitriol *elects* the alkali in preference to the other; and it is termed *single* elective attraction, to distinguish it from others of a more complicated nature, to be illustrated afterwards. It is called, also, *single decomposition*, because there is only one body decomposed.

These cases of chemical action are very useful, especially to practical chemists, because many of the substances formed during their operations, if not themselves of value, may be turned to account by decomposing them, to make them yield their valuable ingredient. Perhaps both of the ingredients are useful; if so, they may both be obtained by single elective attraction, because, after decomposing the compound, and setting free one of its constituents, the newly formed substance which contains the other ingredient, may also be decomposed by another case of single elective attraction, and made to yield it. Suppose we have a compound BC, and we add A to it, between which and B the attraction is more powerful than that between B and C, A will combine with B, and set C at liberty. We thus, then, procure C. Suppose we now wish to obtain B, we must add to the newly formed compound AB, a substance D, between which and A there is a more powerful affinity than that between A and B; D will then enter into union with A, form AD, while B is disengaged, so that we thus procure B. To give an instance of this; suppose we wish to decompose sal ammoniac, which is a compound of muriatic acid and ammonia, so as to obtain both of its ingredients. If we wish to procure the ammonia, after powdering it, we must add to it some slaked lime, and the odour of hartshorn is instantly perceptible, because the attraction between the acid and the lime is stronger than between the acid and the ammonia. Suppose we now wish to obtain the muriatic acid, we have only to add some oil of vitriol, between which and the lime, with which the muriatic acid had united in the former experiment, there is a more powerful attraction than that between the acid and lime already in union; the vitriol and the lime will therefore combine, while the muriatic acid will be disengaged.

Tables have been constructed to point out the order of the forces of affinity of different substances. Thus, the affinity of sulphuric acid is shewn, by placing it at the top, and after drawing a line, putting below it the names

of the substances with which it unites, *in the order of the forces of their affinities.*

Sulphuric acid.
Baryta.
Strontia.
Potass.
Soda.
Lime.
Ammonia.

This at once shews us, that the affinity between sulphuric acid and baryta is more powerful than that between it and any of the others in the table; that between the acid and ammonia is the weakest. If, then, we have the compound of the acid and ammonia, we know that we can decompose it, by adding any of the others; because the affinity between the acid and any of them, is more powerful than that between the acid and ammonia. If we have a compound of the acid and lime, we can decompose it by soda, potass, strontia, or baryta. If, however, we have a compound of the acid and baryta, the table shews us that we cannot effect the separation of its ingredients by any of the others; because the affinity between them is more powerful than that of the acid for any other in the table.—*For the affinity of different bodies, see Appendix.*

The preceding remarks apply to the actions between compounds and simples, or those which act as if they were simple, producing, of course, only one case of decomposition. When we employ two that are compound, and decomposition ensues, the action becomes much more complicated; but still those ingredients, between which there is the most powerful attraction, are imagined to enter into union. Thus, suppose we have two compounds, AB and CD; that is, each containing two ingredients, between which, of course, there is an affinity; but A of the one compound, has an attraction for C of the other, and B for D. If these be stronger than the affinities between A and B, and between C and D, decomposition in-

stantly takes place, when they are presented to each other, A is separated from B, and unites with C, to form AC; while D, sent from C, enters into union with B, to form BD. Here, then, we have two cases of decomposition, AB and CD are decomposed; and we have also two of combination, A and C, and B and D unite. This is called *double elective attraction*, and *double decomposition*, to distinguish it from single elective attraction, or single decomposition. To give an instance of this, we may use common soda and Epsom salts, the former of which is a compound of an acid and the alkali soda, the latter contains an acid and magnesia. When these, previously dissolved in water, are mixed, there is an immediate precipitation of a white powder, owing to the decomposition of both of the compounds, and their ingredients entering into a new state of combination; that is, the soda in the one leaves its acid, and joins that of the magnesia, while the magnesia combines with the acid of the soda, and is precipitated; the other is held in solution.

In these cases of chemical action, the affinities which tend to keep the ingredients already united in that state, are called *quiescent*, while those which are to separate them, are called *divellent;* so that if, when compounds are mixed, the quiescent attractions prevail, there is no action, but if the divellent predominate, decomposition ensues.

These cases of double decomposition have also been illustrated by diagrams. Thus, the following is the diagram of the instance already given:—

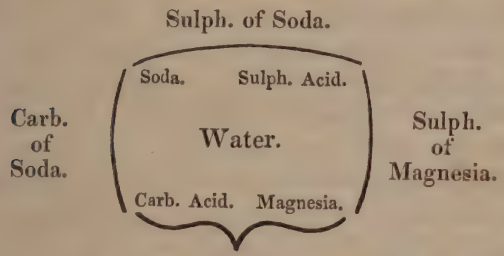


Two lines being made to cross each other, the names of the ingredients of the substances are placed at the ends of these, and so situated, that those between which there is *no* attraction, are diagonally opposite; thus, there is no affinity between sulphuric acid and carbonic acid, nor between soda and magnesia. Those, on

the contrary, between which there is an attraction, are adjoining. Thus, sulphuric acid has an affinity both for soda and for magnesia; and so also has carbonic acid. We may represent the action, by supposing the lines to move on their centre, by which the sulphuric acid and the magnesia, and the carbonic acid and the soda are separated, and the sulphuric acid and the soda, and carbonic acid and magnesia come together; the diagram, after the action, is therefore to be,



Another diagram, is that given by Bergman:



It consists of four brackets. At the sides are placed the names of the compounds used, and at the end of each are those of the ingredients. Thus, sulphate of magnesia is composed of sulphuric acid and magnesia, and carbonate of soda of carbonic acid and soda; and these are so situated, that those between which there is no affinity are diagonally opposite, while those between which there is an attraction are contiguous. At the upper and under bracket, are the names of the compounds that are to be formed with those of their ingredients. Thus, sulphate of soda is composed of sulphuric and soda, and carbonate of magnesia, of magnesia and carbonic acid. In the centre of the diagram is water, shewing that the action has been effected by solution. Had it been brought

about by heat, the word caloric would have been placed there. The lower bracket is broken, and the point turned downwards, which shews that the carbonate of magnesia is precipitated. The upper one is not broken, consequently the sulphate of soda is in solution. Had it been broken, and the point turned upwards, it would have shewed that the compound is gaseous.

These cases of double decomposition, are very useful to practical and analytical Chemists. Many bodies can thus be formed, which cannot be procured in any other way. Thus, the attraction existing among some substances is so extremely weak, that they cannot be made to unite when presented to each other, the powers which have an influence over it, preventing it from producing its effects. When, however, substances of this kind are brought into contact, just as they are set free from combination, they may enter into union. This is called their *nascent* state, (*nasco*, to be born,) because, when set free from combination, they are then, as it were, just brought into existence. Thus, if A be added to BC, and A combines with B, and sets C at liberty, the moment that C is disengaged, it is said to be nascent. A mordant much used by calico-printers is prepared in this way. It is a compound of the acid of vinegar, or acetic acid, and alumina, or earth of clay. Between these there is an affinity, but it is so weak, that when presented to each other, they do not unite; and even allowing that they would, the expense of preparing it in this way would preclude its use. But if compounds containing them be mixed, they may be made to combine, and form the mordant. Thus, when sugar of lead, which contains lead and the acid of vinegar, is mixed with alum, which is a compound of sulphuric acid and alumina, or the earth of clay, there is an immediate decomposition, and exchange of ingredients,—the sulphuric acid unites with the lead, and the acid of vinegar with the earth,—the former is precipitated, while the other is held in solution.

These cases of double decomposition are still farther useful. The attraction between the ingredients of some

compounds is so strong, that it is difficult to effect a complete separation of their ingredients by a case of single elective attraction; but it may be accomplished by double decomposition. Thus, suppose we have a compound BC, between the ingredients of which there is a powerful affinity. On the addition of A, which has an attraction for B, there is no decomposition, because that between B and C is more powerful. On adding D, which has an affinity for C, there is no change, that between B and C being stronger; but if A and D be presented at the same time, decomposition may instantly be effected; because the affinities between A and B, and between C and D, are more powerful than that between B and C. B and C are therefore separated, while A and B, and C and D, unite. To give an instance of this:—If lime be dissolved in muriatic acid, we form a solution containing the two substances, between which there exists a strong attraction. The acid called carbonic acid, has an affinity for lime, and the alkali ammonia has an affinity for muriatic acid; but, on the addition of either of these to the solution, there is no change, because the attraction between the muriatic acid and the lime, is more powerful than that between the carbonic acid and the lime, or that between the muriatic and ammonia; but if the carbonic acid be mixed with the ammonia, and then thrown into the solution, decomposition instantly ensues,—the muriatic acid and lime are separated, and the carbonic acid and lime, and the muriatic acid and ammonia, unite to form two new compounds, the latter of which is held in solution, the former is precipitated.

Different methods have been recommended for ascertaining the actual forces of affinity of different bodies. The only one, at first sight, plausible, is that advanced by Kirwan, and modified in its application by Berthollet. Kirwan imagined that the power of saturation, or neutralization of bodies, was the result of the force of affinity, and hence he conceived that this would prove a measure of ascertaining it.

Thus, suppose 100 of A combine with 200 of B, and

100 of C; it was inferred that the affinity of A for B, is double that of A for C. It is forgot, however, in laying down this rule, that the power of attraction is reciprocal. B has as strong an attraction for A, as A has for B; so that if we apply it in this way, the result will be very different. It has been supposed that A has twice as strong an attraction for B as for C, because it takes twice as much for saturation. If we now take equal parts of B and C, say 200, then 200 of B require 100, while 200 of C take 200 of A for saturation; so that by one way of applying the rule, the attraction of A and B is double, in the other it is only half that of A and C, so that this method is altogether inapplicable.

Proportions in which bodies combine.

With respect to the proportions in which bodies unite, no less than four varieties have been stated.

1*st*, They combine, or appear to do so, in any quantity in which they are presented to each other.

This is well illustrated in the instance of sulphuric acid and water, or of water and spirit of wine. Thus, when a drop of acid is added to a glass of water, the whole of the fluid acquires acid properties. On the addition of more acid, a union takes place, the fluid is still farther acidulated: and again, on the introduction of a third portion, combination is again effected, so that the substances appear to unite in any quantities in which they are presented to each other; and the same occurs in many other cases of chemical action.

2*d*, Bodies unite, or appear to do so, in variable proportions, but only to a certain extent, as is observed chiefly in cases of solution. Thus, in dissolving a salt in water, they appear to combine in different quantities, but there is a limit to their union; the fluid will dissolve a certain portion and no more, but it will take up any quantity less than this. On the other hand, if we have a certain weight of salt, we must take a certain quantity

of water to dissolve it, but it appears to unite with as much more as we choose to add.

3d, Bodies combine in one fixed proportion only. Thus, if sulphuric acid be added to a solution of the earth baryta, each portion put in unites with a definite quantity of earth; and that it does so, in other words, that after the first addition of acid there is still some earth uncombined, is evident, for each addition causes the formation of more and more of the new compound.

4th, Bodies unite in two, three, or more proportions, but these are always fixed, and no compound with intermediate quantities can be formed. Thus, suppose A combines with B, in the ratio of 1 to 1 by weight, but that other substances containing the same ingredients also exist, they will be in the ratio of 1 to 2, or 1 to 3, and these are invariably the same in whatever way the compounds may have been formed. Thus, if tartaric acid be added to a solution of potassa, they unite; and that they do so, is evident from the fluid having neither acid nor alkaline properties. The substance formed in this way remains dissolved, but let more acid be put in, it unites in a definite quantity, and forms a new compound, which is precipitated, owing to its sparing solubility. Now, these two compounds always contain the same proportions of acid and alkali. Numerous other instances of a similar nature occur.

When bodies unite in various proportions, the compounds formed often possess properties totally opposite, the difference being as great as if they were composed of different substances; of which we have a good example in the elastic fluids, oxigen and nitrogen. These, by their union, form atmospheric air, which is absolutely necessary for the support of life. In other proportions, they generate two gaseous bodies, one of which, when breathed, has a remarkable effect on the system, while the other cannot be received into the lungs; but again, by their further union, they form the highly corrosive fluid, aqua-fortis.

On the other hand, it frequently happens that the compound has some of the properties of the ingredient in excess, as in the instance given of tartaric acid and potassa, the last formed substance having decidedly acid qualities. When the properties of the ingredients are destroyed, it is said that they have *saturated* or *neutralized* each other, and the terms *saturation*, or *neutralization*, are used to express the fact. Saturation is, however, employed in another sense. Thus, when a fluid has dissolved as much as it can of a solid, it is said to be saturated. It would perhaps be better to use neutralization for those instances in which the properties are destroyed, and to reserve saturation for cases of solution.

Berthollet is almost the only one who has attempted to assign a reason, why, in some instances, affinity seems to produce combination without limits, and why, in others, there are bounds set to the operation of this law. It has been already mentioned, that, according to him, combination is the result of affinity, modified by external circumstances. Hence he conceived, that were it alone to operate, bodies would unite in every proportion, but that limits are set to their union by the agency of these powers, particularly cohesion and elasticity. Thus, when two fluids combine, and the compound continues liquid, there is neither cohesion nor elasticity to affect the attraction, so that the proportions in which they unite are unlimited. Again, when a solid is dissolved in water, the affinity and the cohesion are at work at the same time, and when the former begins to operate, the latter offers a resistance, but not being so powerful, it is overcome; as, however, the solution proceeds and approaches the point of saturation, the affinity is overpowered by the cohesion, and a stop is put to the farther union. If, however, the cohesion be by any means diminished, the action is renewed, and proceeds till the weakened affinity is no longer able to overcome it, and hence, on applying heat, more of the salt is dissolved. Berthollet asserts, that if we could raise the temperature so as to diminish the cohesion, without inducing elasticity in the fluid, the

union would go on without limitation, were no other foreign power to put a stop to it. With respect to the combination of bodies in one fixed proportion, Berthollet supposes, that when the affinity between them is strong, condensation is the result; at a certain point this will be greatest, and at this, the cohesion of the compound strongest, and thus a limit is put to the union. Thus, in the instance of sulphuric acid and baryta, already mentioned, when they have united to a certain extent, it is supposed that the compound formed acquires such a power of cohesion, that any additional quantity of one of the ingredients cannot combine with the other; besides, the compound is precipitated, and is thus removed from the sphere of action. Here, then, the power brought into play by the operation of the affinity, puts a stop to the farther union; and as this will always take place at the same time, the proportions are thus rendered fixed. When there are two or more compounds of the same substances, it is supposed that the proportions are also determined by the operation of foreign powers; for though in every case there is one point at which the condensation is greatest, and the tendency to cohesion strongest, yet there may be other weaker ones which may also cause the bodies to combine in determinate proportions. Thus, when an acid and alkali unite, the cohesion acquired by the compound, may render the ingredients fixed at this point; but it may not be such as to withdraw it from the sphere of action, so that it is still left to be acted on by any additional quantity of one of the ingredients. Thus, in the instance of tartaric acid and potassa, the first compound remains in solution, not having acquired such a degree of cohesion as to cause it to become solid; but on adding more of the acid, by entering into union with the former, it gradually acquires such cohesion as to cause it to be precipitated, and thus prevent it from being acted on by any excess of one of the ingredients.

The same may be said of elasticity, different degrees of it producing combination in variable proportions.

Such were the opinions at one time entertained, with respect to the combination of different bodies, and the reasons assigned for the difference in the proportions in which they enter into union. Were they correct, it is evident that the union is brought about by affinity, but that the quantities are determined by the circumstances that modify it, the affinity having of itself a tendency to make them unite in every proportion. Though such was the opinion of former chemists, it may be said that it is now entirely abandoned. It is now universally admitted, that when bodies combine, they always do so in *definite proportions;* and that this is purely the result of the attraction existing between them, whatever be the quantities employed, or the circumstances under which the union may take place; and hence has arisen the doctrine of *combination in definite proportions*,—perhaps one of the most important additions which the science has lately received, not only from the general laws which it has brought to light, but from its introducing a facility and an accuracy in analysis formerly unknown. Though perhaps this is not the place at which this important subject ought to be treated of, yet, as much chemical reasoning is founded on it, it may be proper to give here a short account of it. The particular illustrations connected with it will be afterwards pointed out, when giving the chemical history of those bodies, in which combination, in definite proportions, is most remarkable.

Wenzel was the first who pointed out the union of bodies in fixed proportions; but his investigations seem to have been entirely overlooked, till Richter, about 1792, on considering the facts stated by him, again drew the attention of chemists to the subject, but even after this it was again forgotten, till revived by Dalton, about the commencement of the present century. Since then it has engaged the attention of many distinguished chemists, more particularly of Wollaston, Davy, Gay Lussac, Berzelius, Prout, and Thomson, the last of whom has laboured more than any other in this wide field of investigation, (Thomson's First Principles.)

With respect to combination in definite proportions, it is asserted,

1*st*, That bodies always combine in fixed proportions, whatever be the quantities employed, or the circumstances under which the union may be brought about, and that this is purely the result of the attraction existing among them. Thus, if sulphuric acid be added to any fluid containing lead in solution, the acid and metal unite always in the same proportion; and that each quantity of acid added, combines with a definite proportion of the other, is evident, for each addition causes the formation of more and more of the new compound. If, however, we continue to add acid, part of it will remain uncombined; and that this is the case, is shewn by putting in more of the solution containing the lead, by which more of the compound is produced. Now, let this be formed in any other way, its ingredients are always the same.

2*d*, When substances unite in more than one proportion, which is frequently the case, these are not only definite, but it has been found, that the quantity of the ingredient in largest proportion in the one compound, is a multiple by a whole number of that in the other. Thus, suppose A enters into union with B, in the ratio of 1 to 2, if another compound exist with a larger proportion of B, it will be in it, double, triple, or some multiple of 2; that is, it will be 1 to 4, to 6, to 10, &c. Thus, if carbonic acid be added to lime water, a white powder is precipitated, which contains definite proportions of its ingredients; but if more of the acid water be thrown in, the powder disappears, owing to the formation of a new compound, which contains exactly twice as much acid as exists in the first.

The union of bodies in definite proportions, is well illustrated in the action of gases with each other. It was first shewn by Gay Lussac, (Mem. d'Arcueil, 1809,) that they combine either in equal volumes, or the volume of the one bears some ratio to that of the other. If, for instance, one part of oxigen gas be mixed with two of hydrogen, and flame approached, they unite, and form

a new compound, the whole of them disappearing. If equal volumes be taken, and treated in a similar manner, a union ensues; but they still combine 1 to 2, and the same compound is formed; so that one of oxigen is left: and the same occurs though they be used in any other proportion. Farther, if there be two or more compounds of the same gases, the volume of one in the one, is always a multiple of that in the other. Thus, ammonia and carbonic acid form, by their combination, two substances, the one containing equal volumes of acid and alkali, the other having one of the former and two of the latter, so that the ammonia in the last is just double of that in the first. Many instances of a similar nature occur, from which it has been inferred, as a general law, that gases combine in simple ratios by volume; that is, 1 to 1, or 1 to 2, to 3, or to 4. Now, as gases are merely solids converted to the gaseous form, it follows, that if they combine, in definite proportions, by volume, the others must unite in the same way by weight; and as the volumes of one of the gases, in the different compounds, are multiples of that in the first, they must be so by weight in those formed by the union of solids. This was first pointed out by Wollaston, with regard to the alkaline salts. Thus, potassa and carbonic acid form two compounds. If that with the largest quantity of the latter, be mixed with oil of vitriol, the whole of the carbonic acid is set free, and its quantity thus ascertained. If this same compound be heated, carbonic acid is disengaged, equal to half of that got in the other way, and the compound with the smaller proportion is left, so that the one contains just twice as much as the other. What Dr Wollaston pointed out, in this instance, has been found to hold true in others, as the following table, shewing the composition of different compounds, will prove.

Carbonic oxid	is composed of	Carbon	75	Oxigen	100
Carbonic acid	do.	do.	75	do.	200
Protoxid chlorine	do.	Chlorine	45	do.	10

Peroxid chlorine	do.	Chlorine	45	Oxigen	40
Chloric acid is composed of		do.	45	do.	50
Perchloric acid	do.	do.	45	do.	70
Sulphate of potass	do.	Potass	60	Acid	50
Super-sulphate of potass,		do.	60	do.	100

Numerous other instances might be given; but what has been said, will, it is hoped, be sufficient to enable the reader to understand what is meant by the union of bodies in definite proportions, and the different speculations connected with it.

It has been urged against the doctrine of definite proportions, that there are facts contradictory to it, which are the instances of combination illustrated by Berthollet, particularly those of solutions, and in which fluids unite with each other. These, however, when more maturely examined, are by no means exceptions, indeed they afford, particularly cases of solution, strong arguments in its favour. Thus, in the action of fluids, though they appear to unite indefinitely, it has not been proved that mechanical mixture does not exist. If, for instance, a few drops of acid be added to water, they may unite with a definite proportion of the latter, and the new compound will be diffused through the whole; so that each addition of acid will cause the formation of more and more of the compound, till the whole of the water is taken up, and when this is done, the next portion of acid will be left uncombined, but mixed with the other. Again, cases of solution, though they may at first appear to be exceptions, are rather in favour of the opinion, that mechanical mixture does exist. Thus, on adding a few grains of salt, they may unite with a definite quantity of fluid, and form a solution, which is diffused through the remainder of the water. Each addition of salt will cause the formation of more of this, to be mixed with the water uncombined; and that this is really the case, appears to be proved by the fact, that as we continue to add salt, we arrive at a certain point, at which the water will not take up any more; hence we must infer, that the whole of it is already combined, and the only difference between this

and the former is, that as the salt is solid, any excess is left in this state, whereas the former being fluid, it must, though in excess, be mixed with the product of the action, which is also in the same form with itself.

With respect to the second rule, that the proportions of the ingredients in the different compounds are multiples of that in the first, there are certainly instances in which it does not seem to hold true; but even these, if viewed in a certain light, may be considered in favour of the doctrine of proportions. Thus, there are two compounds of iron and oxigen, the first containing 100 of iron and 28.5 of oxigen, and the second 100 to 42.6; now the oxigen in the latter is not a multiple of that in the former. A few other instances of a similar nature occur, but in that given, and in the others, the fractional part is always a half, so that still the exception seems connected with the general law, and the difficulty is easily got over. Thus, we are not certain that, in these cases, we have got the compound, in which the ingredients are united in smallest proportions. If, therefore, we suppose that there is one with a smaller quantity of what we assume as the variable ingredient, the case becomes no longer an exception. Thus, in the instance quoted, there may be a compound of 100 iron to 14.2 of oxigen, and if so, the oxigen in the two others are multiples of that in the first. This mode of reasoning we are warranted in adopting, first, because, as has been already mentioned, the fractional part is always a half; had it been variable, we could not have concluded in what proportion this ingredient might have existed: but, secondly, it has actually been shewn that some of those cases, which appeared to be exceptions, are no longer so, compounds having been found, in which the ingredient in smallest proportion, is just what it was supposed it should be, so as to make it in the others multiples of that in the first. Thus, till lately, only two compounds of sulphur and oxigen were known, the one 100 to 100, the other 100 to 150, being apparently an exception to the general law; but it was inferred that

another existed, containing 100 to 50. This has now been discovered, so that the oxigen in the two long known, are multiples of that in the last. For the same reasons it is expected, that in all those instances in which the doctrine of multiples does not apparently hold true, there will be hereafter discovered compounds containing a smaller proportion of the variable ingredient.

Again, instances occur of substances uniting, and in which apparently the doctrine of multiple proportions is not correct, as in the compounds of lead and oxigen. Thus, the

Protoxid is composed of	-	Lead 130	Ox. 10
Deutoxid do		do. 130	do. 15
Peroxid do.		do. 130	do. 20

Now the oxigen in the second, is not a multiple of that in the first. This objection may, however, be explained away, by supposing that the deutoxid is not an oxid in which the ingredients are in a direct state of combination, but that it is composed of certain proportions of the protoxid and peroxid. Thus it may contain

Protoxid composed of	- -	Lead 130+Ox. 10
Peroxid do.	- - - -	do. 130+do. 20

So that when analyzed, it shall yield 260 of lead and 30 of oxigen, *i. e.* 130 and 15, and that this is really its composition seems proved by the fact, that if it be digested in nitric acid, a salt containing the protoxid in combination with the acid is obtained, while the peroxid is precipitated.

Mr Dalton is the only one who has attempted to assign a reason, why substances combine in definite proportions, and why, when there are different compounds, the ingredients are in multiple proportions. It has been already mentioned, that matter is imagined to be composed of minute particles, or *atoms*, as they are called, and that it is among these that chemical attraction operates. When, then, combination is produced by the operation of affinity, Mr Dalton has asserted that the bodies unite atom to atom, that is, 1 atom of A with 1, 2, 3 or more atoms of B, from which, if correct, it follows, that when there are

more than one compound, the ingredient in largest proportion must be a multiple of that in the other, because the atoms being indivisible, there can be no compound with half an atom. These speculations of Mr Dalton, though they account satisfactorily for the union of bodies in fixed proportions, must, however, be kept apart from the doctrine itself. The one has been established by experiment, the other is merely the attempt to assign a reason for its existence, and whether correct or not, cannot in the least affect the doctrine.

As it is now universally admitted that bodies do combine in fixed proportions, chemists express, by numbers, those in which they enter into union, having of course a standard of comparison. Water is known to be a compound of 8, by weight, of oxigen, to 1 of hydrogen; if, then, we attach to hydrogen 1, that prefixed to oxigen must be 8. Carbonic acid is a compound of carbon and oxigen in the ratio of 1 to 1.33, that is, as 6 to 8, so that, keeping oxigen as 8, that applied to carbon must be 6, and so on with other bodies, we may either find the proportions in which the body will unite with the standard, or with any other substance which has already a number applied to it; thus, if 1 of A unite with 7 of B, and if 7 of B unite with 15 of C, then 15 of C will combine with 1 of A. 15 is the number to be applied to C. Having fixed the numbers of simple bodies, those to be applied to compounds are the sum of those of the ingredients. If A be 1 and B 7, then A B is 8; if C be 15 and D 20, A D is 35; and farther, if A B combine with C D, the number of A B C D is 43, and so on.

It is to be regretted that the advocates of this doctrine have fixed on different bodies as their standard; accordingly, the numbers given to different substances are not the same. Dalton has adopted hydrogen, and called it 1, while Wollaston, Thomson, and others, have chosen oxigen. If hydrogen be taken as the standard, the numbers to be applied to all other bodies are integers, but owing to the small quantity in which it enters into union, they become, in many cases, very high. If oxigen

be used, the numbers are in each case only an eighth of those of the hydrogen scale, and though fractions do occur, yet they are only three, .25, .5, .75, so that small numbers and these fractions are more easily recollected than large ones; besides, one half of the proportional numbers are integers. For this reason, the oxigen scale is usually adopted; and I intend to adhere to it throughout, in giving the proportional numbers, when detailing the chemical qualities of different bodies. Should the hydrogen scale be preferred, it is easy translating the one to the other, for each number, according to the latter, is just eight times greater than those of the former, because each being taken as unity, oxigen is eight times as heavy as hydrogen. Again, Mr Dalton uses the numbers to denote the relative *weights* of the atoms; for, assuming it as a fact, not only that bodies unite atom to atom, but that, when there is only one compound of two substances, they are one atom to one atom, he has endeavoured to ascertain the relative weights of these. Thus, if water be a compound of one atom of hydrogen and one atom of oxigen, and as they are in the ratio of 1 to 8, considering the weight of the atom of the former as 1, that of the latter is 8, and so on with other bodies, so that the numbers applied to them may denote the weights of their atoms. It has been already mentioned, that though the speculations of Dalton account for the doctrine of proportions, we have no proof whatever that bodies combine atom to atom; it would be much better, therefore, that the numbers were used merely as representing the proportions in which bodies unite, because, in stating it in this way, it is expressing a fact, whereas the other is merely the language of hypothesis. This is, however, the expression now generally adopted, and even by those who may use the numbers as denoting only the proportions, so that, when we speak of the atom of a body being 16, we view this either as denoting the weight of its atom relative to that of the standard, or the proportion by weight in which it will unite with it.

The practical uses of a knowledge of the laws of the doctrine of proportions, are numerous and important.

1*st*, By applying numbers to different substances, we can much more easily recollect the quantities in which they unite, and of course the proportions of the ingredients of compounds, than in the usual way of stating them in 100 parts, by which, in each, the numbers of the different substances vary. Thus, to take those of oxigen and nitrogen, according to the old mode, the composition is as follows:

	Nitr.	Ox.
Nitrous oxid,	63.5	36.5
Nitric oxid,	46.5	53.5
Nitrous acid,	30.5	69.5
Nitric acid,	26	74

But according to the atomic doctrine, they are,—

	By weight.		Atoms.		
	Nitr.	Ox.	Nitr.		Ox.
Nitrous oxid,	17.5	10	or 1	to	1
Nitric oxid,	17.5	20	or 1	to	2
Nitrous acid,	17.5	40	or 1	to	4
Nitric acid,	17.5	50	or 1	to	5

2*d*, Should a substance be discovered, by fixing its atomic number by a few experiments, we have the proportion in which it will unite with other bodies, because their numbers point out the proportions in which they combine, not only with the standard, but also with each other. If the standard A be 1, B 2, C 3, D 4, and Z, the newly discovered substance, be found to be 8, which is ascertained by finding the proportion in which it will unite with A, then it will combine with the others in the ratio of Z 8, to B 2, to C 3, to D 4, or some multiple of these. Should it not combine with the standard, we have merely to find the proportional number by uniting it with any other body, and it will then be found to enter into union with all others for which it has an affinity, according to the numbers prefixed to them.

3*d*, It follows from this, that we may have recourse to calculation to correct the result of analytical experiments. Thus, if A be 1, B 2, C 3, D 4, and on analysing a com-

pound of CD, the result gives the proportions, C 3, D 3.9, it is at once inferred, that there is an error in the analysis, and that they ought to have been 3 to 4. Farther, if A and B unite in two proportions, and the analysis gives in the first compound A 1, B 2, but in the second, A 1, B 3.9, it is also inferred, that there is an error, because, according to the doctrine of proportions, the quantity of B in the second compound must be a multiple of that in the first. It is therefore considered to be A 1, B 4.

4th, We are also enabled to explain another very remarkable occurrence,—that when compounds are decomposed, and their ingredients enter into a new state of combination, they are just in such proportions as to neutralize each other, so that there is no excess of any of them. If bodies unite according to the numbers applied to them, and they enter into other states of combination, they must combine again according to these numbers. Thus, suppose A 1, B 2, C 3, D 4, and that AB and CD are united in these ratios; then if A and C, and if B and D unite, they must again do so in the same ratio, A 1, C 3, and B 2, D 4. One instance of this will be sufficient; the composition of

Sulphate of soda is acid 50 soda 40 = 90.
Muriate of baryta is acid 35 baryta 97.5 = 132.5
Sulphate of baryta is acid 50 baryta 97.5 = 147.5
Muriate of soda is acid 35 soda 40 = 75

Now the above table shews that the acid in 90 of sulphate of soda, is just what is requisite for the neutralization of the earth in 132.5 of muriate of baryta, while the muriatic acid in the latter is that requisite for the soda in the former; so that by mixing 90 of the one with 132.5 of the latter, the ingredients enter into a different state of union, and there is no excess of any of them. Should too much of one of the salts be employed, it is left undecomposed. Hence it is, that in many cases of decomposition, there are no apparent marks of action, because there is no disengagement of any of the component parts.

Connected with the doctrine of proportions, are some

remarkable laws with respect to the union of gases. The law laid down by Gay Lussac, has been already noticed, that gases unite in ratios the most simple. There is, however, another very important one with respect to the volume occupied by the product. When gases unite, and the compound is gaseous, there is either no change in the volume, or if there be a diminution or enlargement, it bears a simple ratio to that of one of the ingredients. Thus,

Chlorine 1, Hydrogen 1, give Muriatic acid 2.
Nitrogen 2, Oxigen 1, = Nitrous oxid 2.

So that in the first there is no change in the bulk, but in the last, in which there is a diminution, it is equal to that of the oxigen. The same law is applicable also to the union of gases with solids, the product being gaseous, there being either no change, or the diminution or enlargement bears a ratio to that of the simple gas. Thus,

Oxigen 1 vol. + Carbon give Carb. acid 1.
Oxigen 1 + Carbon = Carb. oxid 2.
Hydrogen 2 + Carbon = Carb. hydrog. $\frac{1}{2}$.

So that in the first the product occupies the same space as the simple gas, in the second the enlargement is the same as the volume of the oxigen, and the diminution in the last is equal to half of the hydrogen

The knowledge of these laws is also of the utmost importance in analytical chemistry, because we are by them enabled to ascertain with the utmost accuracy the specific gravity of compound gases, or knowing their specific gravity, we can infer the proportions of their ingredients. If oxigen give its own volume of carbonic acid, it is evident that the latter must be heavier than the former, by the weight of the carbon with which it has united; so that, deducting the specific gravity of the oxigen from that of the acid, the remainder must be the weight of the carbon, and thus we have the proportion of the ingredients. Again, one of chlorine gas unites with one of hydrogen to form two of muriatic acid, so that its specific gravity must be half the sum of those of its ingredients, because in one volume there is half a volume of each. If two of

nitrogen, and one of oxigen, give two of nitrous oxid, its specific gravity must be the specific gravity of nitrogen, + half that of oxigen, because, as the three are condensed into two, each volume must have one of nitrogen, and half a volume of oxigen, so that the specific gravity of a compound gas is easily found by dividing the sum of the weights of its ingredients by the volume occupied. Nitrous oxid is composed of 2 of nitrogen, and 1 of oxigen, condensed into 2, and the specific gravity of the former is 972.2, and of the latter 1111.1, so that that of nitrous oxid is

$$\frac{972.2 \times 2 + 1111.1}{2} = 1527.7.$$

Since solids combine with gases, and form gaseous products, we may easily conceive that the former has assumed the gaseous form; and thus also we find the specific gravity of this substance, were it in the gaseous state. The specific gravity of oxigen is 1111.1, that of carbonic acid is 1527.7, and as the latter contains its own volume of the former, then $1527.7 - 1111.1 = 416.7$. Again, the specific gravity of carbonic oxid is 972.2, and each volume contains half its volume of oxigen, then $972.2 - 555.5$, half the specific gravity of oxigen $= 416.7$. So that 416.7 must be considered the specific gravity of carbon vapour, could we get it in this state. The same may be done with other solids, and the utility of considering the solid ingredients of gaseous compounds in this way is obvious. Thus, it has been stated, that carburetted hydrogen contains twice its bulk of hydrogen compressed into one, and the specific gravity of this gas is 555.5, that of hydrogen being 69.4. Now $69.4 \times 2 = 138.8$, and $555.5 - 138.8 = 416.7$, so that it is a compound of 2 volumes of hydrogen, and 1 of carbon vapour. But there is another gas containing the same ingredients, the olefiant, and in each volume of which there are also 2 of hydrogen. Its specific gravity is 972.2, now $972.2 - 138.8 = 833.4$, but $\frac{833.4}{2} = 416.7$; so that it contains 2 volumes of carbon, or exactly twice as much as the other.

Connected with the atomic doctrine, and the theory of

volumes, is the general law announced by Prout, (An. of Ph. vi.) that the specific gravity of a gas is easily ascertained, by multiplying its atomic weight (oxigen being the standard,) by 555.5, or half the specific gravity of oxigen; and that it must be so is obvious. If when gases unite atom to atom, they were in equal volumes, it is evident that the atomic weight would represent their specific gravity, but this is rarely the case; indeed, considering oxigen as the standard, and supposing its atom to be represented by a volume, those of other gases are denoted by two volumes. Thus, water which contains an atom of each of its ingredients, is composed of 1 of oxigen, and 2 of hydrogen. Nitrous oxid, consisting also of an atom of each of its constituents, consists of 1 of oxigen, and 2 of nitrogen, so that since the atoms by volume are 2 to 1, their specific gravities are not as their atomic weights, but as the atomic weight of the one, multiplied by half the specific gravity of the other. Thus, oxigen being 1111.1, that of hydrogen is 69.4, its atom being 1.25; and that it is so, the above formula will shew.

$$1.25 \times 555.5 = 69.4.$$

The atomic weight of nitrogen is 17.5, and $17.5 \times 555.5 = 972$, which is its specific gravity.

Connected also with the atomic doctrine, is the sliding scale of chemical equivalents, constructed by Wollaston; for an account of which, see *Appendix*.

PART II.

SECTION I.

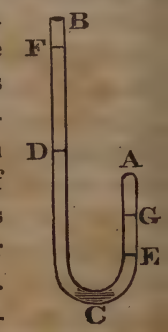
ATMOSPHERE.

Before proceeding to detail the chemical qualities of different bodies, I think it proper to state a few of the mechanical properties of the air of the atmosphere, because it is necessary that the reader be made acquainted with the leading facts concerning the pressure of the air, which has so important an influence over many of the operations of chemistry; indeed, it is impossible to carry on some of these, and at the same time exclude its agency. It must not, however, be supposed, that I am to enter fully into this subject, as it is one properly belonging to mechanical philosophy.

The air of the atmosphere, or that mass of aerial fluid which surrounds the globe, has, since experimental philosophy began to flourish, been a subject of particular interest, more especially with respect to its mechanical properties, which were sooner made known than its chemical ones.

Air is inodorous and tasteless; it is also transparent and colourless, hence of course it is invisible. It possesses the three distinctive mechanical properties of all aeri-

form fluids, *tenuity*, *compressibility*, and *elasticity*.—By tenuity is meant, that the particles are far removed from each other. The specific gravity of air is reckoned 1000, other aeriform substances being referred to it as the standard. At 60 F. and barometer 30, 100 cubic inches weigh 30.5 grs.—By *compressibility* is meant, that the particles may be brought nearer each other, or that it may be made to occupy less space than it naturally does. Thus, if it be subjected to pressure, it is diminished, as is shewn by taking a bent tube shut at A, and open at B. By pouring in a little mercury, so as to occupy the bent part at C, air is confined in the shorter limb, and we can subject this to pressure by putting in more mercury, say to D, by which that in the opposite one rises, say to E, proving that the air is reduced in volume. If it be poured in to F, it will rise in the other, say to G, shewing that it is still farther diminished. It has been proved by experiment, that the diminution is in proportion to the pressure: That is, if twice the pressure which it usually sustains be applied, it is reduced to one half, if four times the pressure, to one fourth, and so on. Some experiments have been lately performed by Mr Perkins, by which it is said he has been enabled to apply so great a compressing force, as actually to cause it to become liquid.



It is remarkable that, in compressing air, caloric is evolved, and if the compression be sudden, the heat generated is sufficient to set fire to inflammables. In working the condensing syringe of an air gun, it always becomes warm. Here, however, much of the heat evolved must depend on friction, but by a particular contrivance tinder can be kindled, or even gunpowder exploded, merely by the condensation of air, and if the apparatus in which the compression is effected, be terminated by a glass tube, light is observed to be disengaged. The practical application of this fact has been already explain-

ed, (see p. 86.) and the opinions entertained with respect to the generation of the heat, have been given at p. 87.

As the pressure is removed, the air regains its former size, or if part of that which it always sustains is withdrawn, it enlarges; hence it is said to have *elasticity*. The elasticity of the air is shewn by placing a bladder half full of it, under the receiver of an air-pump, and exhausting; as we withdraw the air, in other words, diminish the pressure, the bladder becomes distended, from the enlargement of that within it; indeed, the whole operation of the pump itself depends on the elasticity of the air; for when the piston is drawn up, by which a vacuum is produced, that in the receiver, owing to its elasticity, expands, and part of it rushes into the syringe. When the piston is forced down, this is expelled through the valve; and on again raising it, more is drawn out, so that, by alternately raising and depressing it, almost the whole may be withdrawn. It is evident, however, that the whole cannot be taken out; for when the elasticity of what remains in becomes trifling, it ceases to move the valve, so that any farther working of the pump does not withdraw more. The more easily, therefore, the valves are moved, the more nearly does the vacuum approach to a perfect one.

Experiments have shewn, that the enlargement keeps pace with the diminution of pressure; that is, if one-half of the original pressure be removed, it is doubled in its volume, and so on.

Air is also possessed of *weight;* but this differs according to the height of the place at which it is taken. As that below sustains all above it, it is much compressed, and is therefore the heaviest. The weight of the air, in other words, the *pressure of the atmosphere*, is proved in many ways. If a receiver be placed on the plate of an air-pump, and exhausted, we are unable to move it, because it is kept down by the weight of the air around it. If, instead of using the receiver for this experiment, a white iron cylindrical box be employed, as

the air within is withdrawn, the sides are driven in, not being able to sustain the weight of that around it. Or if a long tube, with a stop-cock, be exhausted by the pump, and then have the cock opened under water, the fluid will be forced in by the pressure of the air on the surface of that in the basin. It has been ascertained by experiment, that the pressure of the air is, on an average, equal to 15lb. on the square inch, which is the same as that of a column of mercury of 30 inches. If, therefore, a long tube, shut at one end, be filled with mercury, and inverted in a cup of the same fluid, only part escapes; there will remain about 30 inches, retained there by the pressure of the air on the surface of that in the cup. Were the pressure increased, the mercury would stand higher; were it, on the contrary, diminished, it would be lower, and hence the use of a tube containing mercury, and inverted in a basin of it, as a measure of the pressure of the atmosphere; and as the air varies in weight, according to its state with respect to dryness and moisture, we have thus an indication of any change likely to take place in the weather. The instrument is called a barometer, βαρυς, *heavy*, and μετρον, *a measure*. If the mouth of the tube, in the former experiment, be plunged under water, the mercury will escape, and the water will rise; but, in this case, it will fill the tube, because, being lighter, the air can sustain a greater column of it. It has been found, that the pressure of the air is equivalent to that of a column of water, of about 34 feet; so that, if the tube were of this length, the water would fill it, being forced in by the pressure of the air. Hence it is that we are enabled to raise water only to a certain height in a pump; for when the piston is drawn up, a vacuum is produced, which is immediately filled by the fluid at the bottom being forced in by the air pressing on it; but when this is brought up to about 34 feet, any further working does not elevate the water more, because, though a vacuum be produced, the pressure of the air cannot sustain a longer column.

From what has been said of the pressure of the atmosphere, its agency in some experiments previously noticed will now be apparent. In the filling of thermometers, (see p. 14.) and in the experiment by which the condensation of vapour was proved, (p. 67.) it was it that caused the rise of the fluid into the apparatus.

Since the lower column of air sustains the pressure of that which is above it, we must pay particular attention to this circumstance, when experimenting on it, because it must change its volume according to the pressure, and unless, therefore, we know that to which it is subjected, we may be deceived with respect to the actual quantity on which we are operating.

The volume of air confined in jars, over fluids, may be altered in three ways:—1*st*, By the pressure of the atmosphere varying.—2*d*, When the fluid over which the jars are standing, is not on a level on the outside and inside.—3*d*, By an alteration of temperature.

1*st*, As the change of pressure causes a variation in the bulk of air, it has generally been agreed on, in stating the results of experiments, to fix on a certain pressure as a standard. This is when the barometer is at 30. In experimenting on it, should the barometer not stand at 30, or should any variation have taken place during the performance of the experiment, we must make allowance for it; which is done by the following formula.

To reduce air at any pressure, to a standard pressure, (bar. 30.) multiply the volume by the pressure, and divide the product by 30. Thus, suppose we have 20 cubic inches at 29, and wish to know what space they would occupy at 30,

$$20 \times 29 = 580 \text{ and } \frac{580}{30} = 19.3$$

so that 20 cub. inches at 29 would be 19.3 at 30; of course this applies whether the pressure is greater or less than the standard, and by it also the volume at any pressure can be ascertained.

2*d*, When air is confined in a jar, and the fluid not on a level, it does not sustain the usual pressure,

and is therefore not of the proper bulk. If it be highest on the outside, the air is diminished, because, in addition to the usual pressure, it has that of the column of fluid; if, on the contrary, it is highest on the inside, it is enlarged, because some of the pressure being spent in keeping the fluid in the jar, the air over it is deprived of a part, in other words, it has the pressure of the atmosphere *minus* what is necessary to sustain the column of fluid. If mercury be employed, the change in volume, owing to its weight, is considerable. In experimenting on air in jars, standing on a water or mercurial trough, we must attend particularly to this circumstance; if the trough be deep enough, we ought always to bring the fluid to a level, and this must be attended to especially with mercury, because, owing to its great weight, any slight difference makes a considerable variation in the bulk. If we cannot bring the fluid to a level, allowance must be made by the following formulæ.

If the fluid be *highest on the inside, subtract its height from that of the barometer, multiply by the volume of air, and divide by the standard pressure.* Thus, suppose 20 inches of air in the jar, and the mercury three inches above the level,

$$30 - 3 = 27 \times 20 = \frac{540}{30} = 18$$

So that 20, were the mercury at a level, would be 18.

If the fluid on the outside is highest, then, instead of subtracting, we must *add the height of the fluid to that of the barometer, multiply by the volume, and divide by the standard.* Thus, suppose the fluid 3 inches higher on the outside than the inside, and we have 20 inches of air:

$$30 + 3 = 33 \times 20 = \frac{660}{30} = 22$$

By dividing by 30, the standard height of the barometer, we reduce the air to the space it ought to occupy, were the fluid on a level, and were the barometer at the average height.

As the pressure of the atmosphere can support a

column of water of 34 feet, or 408 inches, we must use this instead of 30, when air is confined over it. Thus, suppose as before, the difference is 3 inches,

$$408 - 3 = 405 \times 20 = \frac{8100}{408} = 19.85$$

$$\text{or, } 408 + 3 = 411 \times 20 = \frac{8220}{408} = 20.14$$

3d, The volume of air may be varied by a difference in temperature. Air does not suffer any alteration by the addition or abstraction of heat, excepting a change of volume: but different statements have been given of the change produced. Sir G. Shuckburgh asserts, that in rising from 32 to 50, it is increased 1-412th part for each degree. Roy, on the contrary, says that the increase is 1-419, while De Luc makes it 1-480, with which the experiments of Dalton, (Manchester Mem. v.) and Gay Lussac, (An. de Ch. xliii.) very nearly agree. This is now universally allowed to be the change effected; 1-480th part for the addition of a degree at 32. Knowing this, we can easily reduce the volume from any temperature to the standard 60 F. or to any other temperature, by the following formula.

Add the number of degrees which the gas is above 32, to 480, and we get the first number of the formula. Add the number of degrees which the required temperature is above 32, to 480, and the product will be the second number. The volume of the air at the given temperature, is the third, and the fourth will give the volume required. (An. of Ph. vi. N. S.)

Thus, it is wished to know how much 100 cubic inches of air, at 60, would occupy when heated to 96.

$$60 - 32 = 28 + 480 = 508$$
$$96 - 32 = 64 + 480 = 544$$
$$508 : 544 : : 100 : 107.08.$$

Suppose the temperature is to be reduced. Thus, the volume of 100 inches, when reduced from 75 to 40, is required.

$$75 - 32 = 43 + 480 = 523$$
$$40 - 32 = 8 + 480 = 488$$
$$523 : 488 : : 100 : 93.3.$$

According to Davy, (Phil. Trans. 1823,) the expansion of air by heat is the same, whatever be the density. If, for instance, it be under double its usual pressure, that is, reduced to one half, and heat applied, the enlargement is just the same as if air of usual density were employed.

The preceding remarks, with respect to the change produced in the volume of air, whether by an alteration in the pressure of the atmosphere, or of temperature, or by the fluids in the jars not being on a level, apply to all bodies in the aeriform state. It has been found by numerous experiments, that all gases are equally changed by equal alterations of temperature, or pressure, so that should any gas be the subject of experiment, the required volume is found by the same formulæ. Hence, it is unnecessary, in detailing the chemical history of gases, to state the changes produced by the variation of pressure or temperature.

Among the ancients, air was considered one of the elements. About the middle of the last century, Hooke and Mayow inferred, from its supporting combustion, that it was a compound; but this was mere conjecture, they did not support their opinion by experiment. It was not till towards the end of the century, that it was discovered to consist of different ingredients. The experiments of three chemists, performed nearly about the same time, and unknown to each other, proved satisfactorily that it is composed of two substances, possessed of opposite properties, one supporting combustion and respiration, the other having neither of these qualities. Besides these, air contains other substances, but which may be considered adventitious,—they are watery vapour, and the elastic fluid called carbonic acid. But the consideration of this subject will again be resumed, after having described the properties of the ingredients of the air, oxigen and nitrogen.

SECTION II.

ACIDIFYING AND ALKALIFYING PRINCIPLES *.

OXIGEN.

Equivalent 10, or 1 by hydrogen scale; symbol O; combining measure □ (one volume.)

The merit of the discovery of this important substance, perhaps the most widely diffused and energetic in nature, is due to Priestley, Lavoisier, and Scheele. These eminent chemists were nearly about the same time carrying on experiments in different countries, by which each, unknown to the others, discovered the elastic fluid, and proved it to be a distinct body. Priestley has, however, the merit of priority. In 1774, he procured a quantity of it, by exposing to the sun's rays, concentrated by a lens, the substance called red oxid of mercury, but better known by the name of red precipitate, by which an aeriform matter was disengaged, having the power of supporting combustion with a flame much more brilliant than that in atmospheric air. Scheele in 1777 obtained it, by subjecting nitre or saltpetre to heat; and Lavoisier procured it in the same year, by a process similar to that of Priestley.

Since its discovery, it has had different names. It was at first termed *vital* and *empyreal* air, from its power of supporting respiration and combustion, and from a hypothesis which at one time existed with respect to the

* By the term *alkali*, is here meant a salifiable base, or one which, with an acid, will form a salt.

nature of the latter, it was termed *dephlogisticated air.* These have, however, now given way to that of oxigen, derived from a property to be immediately mentioned.

Oxigen gas is transparent and colourless, hence it is invisible. It has neither taste nor smell. It of course possesses the three distinctive features of all aeriform bodies, tenuity, compressibility, and elasticity. It is heavier than atmospheric air; but different statements have been given of its specific gravity. According to Kirwan it is 1103, to Davy 1127, and to Allan and Pepys 1108. Dr Prout and Dr Thomson, however, make it 1111.1, which is generally considered to be correct.—100 cubic inches at 60 F. and Bar. 30, weigh 33.9 gr.

Caloric causes no change in it, except in volume, the expansion following the law mentioned, 1-480th part for each degree at 32. It has not yet been condensed, either by the abstraction of heat, or by pressure.

Light has no action on it. It has been mentioned, however, by Biot, that light is disengaged, when glass balls filled with it are broken *in vacuo,* and from which he infers that the light proceeds from the gas itself. Others have, however, asserted, that it is extricated by the particles of glass rubbing violently against each other, which is rendered probable by the discoveries of Mr Hart, (Lond. Journ. XV.) that air discharged from an air-gun, emits light only, when particles of sand, or other hard substances, adhere to the wadding, and rub against the sides of the barrel during the discharge.

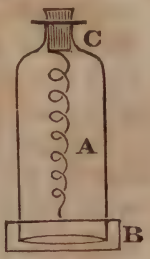
The distinguishing feature of oxigen gas, is its power of supporting combustion and respiration. Many inflammables, when put into it, instantly take fire; but others require an elevation of temperature, and all of them burn in it with great splendour. If, for instance, a candle which has just been extinguished, but still having the wick red, be put into a vase of it, it is kindled, and burns with a bright white flame.

Phosphorus burns in it with astonishing splendour. For this purpose, having filled a vase, A, with it, introduce a small piece of phosphorus, resting on a copper



cup and stand, B, and then touch it with a hot wire, and place a piece of tinned iron on the mouth, C. The moment the phosphorus is heated, it takes fire, and the combustion is brilliant, though of short duration. In this experiment, it is necessary to have the vase placed on a large plate, because, owing to the sudden generation of heat, it is apt to be broken.

Some of the less inflammable bodies also burn in oxigen gas. Thus, when iron in the state of fine wire is heated in it, the combustion becomes very brilliant, and it can be shewn, at the same time, that the gas is consumed. For this purpose, into a jar of the gas A, open at both ends, and standing on a plate of water, B, introduce at C, a coil of very fine iron wire, the end of which being tipt with sulphur, is previously kindled. It instantly becomes red hot, and is gradually consumed, emitting a bright white light; at the same time, if the cork to which it is fixed at C, is tight, the water will rise, and fill the jar, being forced up by the pressure of the atmosphere.



Numerous other instances of combustion in oxigen, will be afterwards given when describing the qualities of the substances with which it acts. In many of these, the product of the action has acid properties; and hence the name of oxigen, derived from the Greek words ὀξυς, *acid*, and γενναω, *to generate*, being at the time this was given it, supposed not only to generate acids, but to be the only generator of these bodies. Though by its union with others it forms compounds not acid, and though it is now known that acids exist which do not contain oxigen, yet the name is still retained.

Oxigen gas is likewise necessary for the support of life, as an animal, when deprived of it, quickly dies. If one be confined in a given quantity of it, it will live much longer than in the same bulk of air; but pure oxigen does not seem well adapted for respiration, for an animal dies in it, even though enough is left to support

the life of another for some time. The death seems to be occasioned by its powerful stimulating effects; and hence, in the air of the atmosphere, it is greatly diluted with another gas, which appears to possess negative qualities on the animal system.

Oxigen is a universally diffused body; a large part of the air is composed of it, (*See Nitrogen.*) It is also a component part of many other bodies presented by nature. It does not, however, occur any where pure; we are obliged, therefore, to have recourse to the decomposition of its compounds, when we wish to prepare it. That from which it is usually procured for common purposes, is oxid of manganese, *(See Manganese)*; but when required for particular experiments, it is generally obtained from red oxids of mercury or of lead, or from chlorate of potassa, *(which see.)*

Soon after the discovery of oxigen gas, it was thought that the breathing of it would prove of great service to those affected with pulmonary complaints; but the accounts given of its effects are very contradictory, some asserting that it really was useful, while others stated not only that it was of no service, but that it proved injurious. Oxigen gas, mixed with from 1-20th to 1-10th of nitrogen, the other ingredient of the atmosphere, has been breathed, and it is said with the utmost success, in a case of dropsy of the chest.

It has been already mentioned, (p. 156.) that chemists now attach numbers to different substances, according to some, to show the proportions in which they enter into union, according to others, to denote the weight of their atoms; but of course a standard is necessary, as it is only by comparison that we speak of the atoms. For this purpose, most have chosen oxigen, while some have fixed on hydrogen. It is unnecessary to state the numbers given by different authors; it will be much better, as less likely to create confusion, to keep to one throughout. I adopt oxigen, because, taking it as 10, the numbers to be applied to other bodies are small; besides, it is the standard of Dr Thomson, who has laboured most in the

elucidation of the atomic doctrine. We are to consider, then, the atom of oxigen as 10.

HYDROGEN.

BEFORE proceeding to detail the properties of hydrogen, as it belongs to the class of substances long known by the name of inflammables, it is necessary to state the different circumstances concerning inflammation or combustion, and to give briefly the opinions which have been entertained respecting its nature.

The remarks to be made apply chiefly to common cases of combustion, that is, to combustion carried on in the usual way in atmospheric air.

Combustion.

By combustion is meant that certain bodies, when heated to a due pitch, begin to emit both heat and light, and which they contiuue to do for some time; they seem also to be consumed, at least the products are in many cases not apparent.

The substances that undergo this change, are called *inflammables* or *combustibles*. A combustible is easily distinguished from an incombustible. When heat is added to the latter, it arrives at the temperature of the surrounding medium; but the moment that we cease to apply it, its temperature falls. When, on the contrary, the former is heated to a certain height, it gives forth heat and light, and continues to do so for some time, though the means by which its temperature was raised is withdrawn.

It has been said, that some inflammables appear to be annihilated during combustion. Thus, when strong spirit of wine is kindled in a saucer, the whole of it disappears. But, in this case, it is not annihilated; it is merely changed into other bodies which we do not observe, because they are in the gaseous form. That the substance is not annihilated, may be shewn by setting fire to a piece of phosphorus, and putting a bell glass over it, by which a white flaky matter is formed, and deposited on

the sides of the apparatus. The same is the case in every instance, the inflammable being merely converted into another body.

Some bodies burn with a bright flame, while others give out very little light. It is remarkable, also, that inflammables emit different coloured lights. In general, those that burn at a low temperature disengage the most refrangible rays; thus, sulphur, when burning slowly, has a blue flame. Those, on the contrary, which require a high heat for their combustion, give out the least refrangible rays. Charcoal which excites an intense heat, emits red light copiously. When the temperature is very high, and the combustion rapid, the different rays are emitted in due proportion, constituting white light.

To keep up combustion, air, or some body that will supply oxigen, is necessary. A candle will not burn in an exhausted vessel; the flame is even extinguished, unless the air be renewed. Thus, if a lighted taper be put into a jar of air, standing over water, the combustion continues but for a short time.

Air, also, in which a candle has been burned, is reduced in volume, and its properties are completely changed, but to shew that this is the case, some contrivance must be resorted to, to prevent its escape when expanded by the heat. If sulphur or phosphorus, A, be kindled, and a jar open above and below, B, but having a tube with a bladder fitted to the upper aperture, C, be placed over it, the air at the bottom being confined by water in a basin, D, the combustion continues but for a short time; and after it has ceased, and the apparatus become cold, the fluid rises in the jar, E, shewing that part of the air has been consumed. If a taper be put through the upper aperture, into the residual gas, it is extinguished, but before doing this, it is necessary to pour in water into the basin, to bring it on a level with that in the inside, and thus, when the stopper is removed, prevent the admission of air.



When a substance is deprived of its inflammability, this can be easily restored by subjecting it to heat along with another inflammable, but excluded from the air. Thus, if the product of the combustion of phosphorus be heated in an earthen retort with powder of charcoal, a substance comes off which is inflammable; in fact it is phosphorus, the body with which it had previously united during its combustion having been taken away by the carbon.

So early as the year 1665, Dr Hooke threw out the conjecture, that there is something in air which has the property of dissolving combustibles, when its temperature is elevated, and that the solution goes on so rapidly, as to occasion the emission of heat and light, which were by him considered merely motion. He even supposed that this substance is the same as exists in nitre or saltpetre, an opinion which was afterwards for a long time entirely neglected. How far he was right, and how nearly he anticipated Lavoisier and others in their brilliant discoveries, will be immediately noticed. Becchar afterwards proposed an explanation of combustion, altogether different from that of Hooke, which was more fully illustrated by his pupil Stahl, so much so, that it received the appellation of the Stahlian doctrine, and which was soon afterwards espoused by almost all philosophers, and continued for a long time to sway their opinions.

Stahl conceived that there was contained in all inflammables, a principle which, when extricated, produced the phenomena of heat and light. Becchar, who first threw out the conjecture, supposed that it was matter, and gave it the name of *inflammable earth;* but Stahl considered it merely as the cause of heat and light, and called it *phlogiston*, and hence his doctrine has been termed the phlogistic doctrine.

Phlogiston was supposed to be the same in all bodies. By its extrication heat and light were produced, and it assumed its proper elastic form, the substance from which it was evolved, becoming no longer inflammable; owing to its subtlety and tenuity it could not be collected, so

that its presence was known only by its effects. It might be made to pass from one body to another, and impart to it inflammable properties. Other remarkable qualities were also attributed to it, such as its communicating ductility and malleability to metals.

Stahl, in advancing the doctrine of phlogiston, overlooked a very material point. It was natural to suppose, that when a body parted with it, it should become lighter. It was soon, however, discovered that the reverse was the case, the substance, after undergoing combustion, in other words giving off its phlogiston, actually becoming heavier. When this was ascertained, it was brought forward as an objection, and certainly a very strong one, to the hypothesis; but it was very easily obviated by its supporters, by attributing to phlogiston another and very remarkable property, that it was actually possessed of levity, consequently, when added to a body, it made it become lighter, and of course, when the inflammable underwent combustion, and parted with its phlogiston, it became heavier, being deprived of something which had communicated lightness.

Though it had been shewn that atmospheric air had an influence over combustion, Stahl completely disregarded this in advancing his opinions; but when it was clearly established, not only that it was necessary, but that it was actually changed in its properties, it was imagined that it drew the phlogiston from the inflammable, and by uniting with it thus became vitiated.

With all these glaring deficiencies, the doctrine of Stahl, under these modifications, stood its ground till the discoveries of chemists with regard to elastic fluids, different from that of the atmosphere, again drew their attention more particularly to it. At this time the actual existence of phlogiston had not been proved; at last Kirwan endeavoured to shew that it was the light aerial fluid hydrogen, which he imagined entered into the composition of every inflammable, and which during combustion was liberated and united with the air.

During the time that philosophers were busily engag-

ed with these disputes, Lavoisier was employed in examining the phenomena of combustion, which he was induced to do by the numerous strong objections that had been urged against the phlogistic doctrine, as of the body becoming heavier, and the air being vitiated by this process; but he seems to have had his attention drawn to the subject more particularly, by some experiments on the calcination of metals. These made him at first doubt the hypothesis of Stahl, and at last, after numerous well-conducted experiments, he boldly asserted that there was no such thing as phlogiston, and that all the phenomena of combustion could be satisfactorily accounted for without it. He clearly proved that the presence of air, or of some body that could furnish *oxigen*, was indispensable, that it was diminished in volume, and that the inflammable itself became heavier, owing to its union with the oxigen. He even shewed that the weight acquired by the latter, was equal to the loss sustained by the former, and also that the oxigen which thus united with the inflammable, could again be communicated from it to another, or could even be obtained in its pure state; and when thus procured, it was found to be equal in weight to that abstracted from the air. From these and other discoveries, Lavoisier maintained that combustion depended on the union of an inflammable with oxigen.

In attempting to account for the evolution of heat and light, Lavoisier naturally had recourse to the important discovery of Black, with respect to the emission of heat, during a change of form. He conceived that the oxigen of the air, in combining with the inflammable, gave forth that large quantity of caloric, which was necessary to keep it in the elastic form. He, however, extended this a little farther. He considered oxigen gas a compound of the matter of fire, and an unknown base, the latter of which entered into union with the inflammable, while the former, being evolved, caused both heat and light.

When the theory of Lavoisier was first made known, such was the blind adherence to the opinions of Stahl, that it met the most violent opposition, and it was not

till after a long time that the French chemists avowed themselves converts to it. At last the doctrine of Phlogiston was completely abandoned, and the more rational theory of Lavoisier substituted in its place; at least, that combustion depended on the union of an inflammable with oxigen; for Lavoisier very properly separated the facts, by which he established the truth of his doctrine, from the hypothetical part, by which he endeavoured to explain the origin of the heat and light *.

Though it is now universally admitted, that the phenomena of combustion are occasioned by the union of an inflammable with oxigen, we are as yet undecided with respect to the origin of the heat and light, some supposing that they proceed from the oxigen, others that the caloric comes from it, while the light is emitted by the combustible.

It has been already mentioned, that two opinions are entertained concerning the state in which caloric exists in bodies. According to some, only part affects the temperature, while the remainder is in strict chemical union; according to others, bodies having different capacities for caloric, they contain different quantities; but the whole of it affects the thermometer.

Lavoisier, and those who adopt the former of these opinions, have maintained that the oxigen unites with the inflammable, and that the combined caloric, that which kept it in the aeriform state, is set free, because there exists a greater attraction between the inflammable and the base of the oxigen, than between the base and the caloric. A different view of the subject has, however, been proposed by Crawford, founded on the doctrine of capacity advanced by Irvine, and which was applied by him to account for the generation of heat and cold during chemical action. He examined carefully the capacities of oxigen gas, of the different inflammables, and of the

* From what has now been said, it will be observed how very nearly Hooke anticipated Lavoisier in his great discovery; in fact, the latter has merely proved by experiment, what the former had only conjectured was the case.

products of their union, and having found that those of the last were below the mean of those of the others, he concluded that the evolution of heat was caused by the diminution of capacity. He even went farther. He ascertained that the capacity of oxigen gas was very high, while that of most of the inflammables was low, that of the product being above that of the combustible; consequently, he maintained that the caloric could not come from it, but from the oxigen, owing to the very great diminution which it suffers by its entering into union.

Though the doctrine of Crawford is the one usually received, yet the experiments of De la Roche and Berard not only very much invalidate it, but, if correct, will completely overturn it. They assert (An. of Ph. II.) that the capacity of oxigen is not nearly so high as Crawford makes it; instead of 4749, it is, according to them, only 236, water being 1000. They also state, that the capacity of the product of combustion, is in many instances greater than the mean of those of its ingredients; if so, it is evident that the explanation given by Crawford is incorrect, but as yet their experiments have not been confirmed by any other chemist. There are many cases, however, in which it appears, that the supposition of the caloric coming from the oxigen is erroneous. Thus, in the instance of gunpowder, or of any mixture of inflammable matter with nitre, which contains a large quantity of oxigen, this substance has laid aside its aeriform state, and ought not therefore to contain so much caloric as when gaseous. Besides, instead of there being a change from gas to fluid or solid, which the explanation of Crawford presumes, there is a generation of a large quantity of aeriform matter, which is the cause of the explosion, so that, instead of the evolution of heat, we should expect the production of cold. Though these cases appear strong in opposition to the theory of Crawford, yet there is one method of getting quit of the objection, particularly in those in which there is actually a change from solid to gas. It has been already mentioned, (p. 86.) that when air is suddenly compressed, heat

is evolved. Now, when gunpowder is exploded, by which there is a formation of gaseous matter, the air around must be suddenly condensed, and thus may evolve heat. The same may be extended to other cases of combustion; for it is well known, that in blast furnaces, in which the heat is very intense, a great deal depends on the free admission of air, part of which is to keep up the combustion, part, by its expansion and consequent compression of that around it, to cause the evolution of caloric, (Ed. Ph. Tr. 1825.)

The emission of light is still to be accounted for. It has been already mentioned, that Lavoisier imagined that the light was extricated by the oxigen, which he supposed to be a compound of the unknown base and the matter of fire; accordingly, during combustion the inflammable and the base united, while the heat and light were evolved. There are many circumstances, however, which seem to prove, not only that the light does not come from the oxigen, but that it proceeds from the inflammable. Thus, a product of combustion will afford its oxigen to another body, and, at the same time, there is an evolution of light. Had the oxigen ever contained it, it ought to have parted with it when it entered into union with the first combustible; so that, in these cases, the light could not proceed from the oxigen. It may be argued here, however, that if this substance can enter into union, and retain its caloric, why may it not also retain its light, supposing it to have been in combination with both? Allowing that this is the case, which has not, however, been proved by experiment, there are instances in which certain inflammables can combine with each other; and though the access of air is excluded, yet light is evolved, from which it would appear that it proceeds from the inflammable; at least, the facts are at variance with the supposition, that it is evolved by the oxigen.

Such are the opinions advanced with respect to the origin of heat and light during combustion, taking it for granted that they are agents altogether different. If,

however, it be supposed that they are one and the same, their evolution must be accounted for, by supposing, that during the chemical action, the substances, owing to the power of retaining them being diminished, set a portion free, and that, by some means, part assumes the appearance of the other.

The preceding remarks apply to combustion in its most limited acceptation,—that it is the emission of heat and light during the union of an inflammable with oxigen. It is now, however, almost universally admitted, that it may be occasioned by the combination of inflammables with other bodies, as with chlorine and iodine, both of which, when acted on by others, cause the appearance of heat and light. If this opinion be correct, the same speculations, with respect to the sources of these agents, will apply to it as to common cases of combustion.

Though some have thus wished to consider combustion as the union of an inflammable with what is called a *supporter*, there are many who take a much more enlarged view of the subject, and it is perhaps the most correct. They suppose it to be the evolution of heat and light, during any case of chemical action. Thus, iron filings and sulphur, both of which are commonly considered inflammables, emit them during their union, even though the experiment is performed *in vacuo*; and the same is the case with many other bodies. In accounting for the evolution in these cases, we must have recourse to the same speculations as before, that they are contained in the bodies, and that they are disengaged probably by a change of form, and consequent change of capacity.

HYDROGEN.

Hydrogen, in a pure state, exists at a natural temperature in the gaseous form. It was early discovered by chemists. Mayou, Boyle, and Hales, described a few of its properties; but we are indebted to Mr Cavendish for

the first full account of it. He gave it the name of *inflammable air*, which was afterwards changed by the French nomenclators to *hydrogen*, derived from ὑδωρ, *water*, and γενναω, because it enters into the composition of that substance.

When pure, it is a transparent and colourless gas; hence it is invisible. It is destitute of taste and smell, but, as generally prepared, it has a disagreeable odour, owing to impurities derived from the substances from which it is procured, according to some, from the presence of volatile air, according to others, from the union of the hydrogen with sulphur, phosphorus, or carbon. That pure hydrogen is inodorous, is shewn by passing it through alcohol, charcoal, nitric acid, or lime water, by which the impurities are absorbed, and it is deprived of its smell.

Its atomic weight is 1.25, compared to oxigen as 10.

It is the lightest gaseous substance, consequently the lightest body with which we are acquainted. Its specific gravity has, however, been differently stated, probably owing to its various degrees of purity. According to Biot and Arrago, it is 732, and according to Berzelius 688, air being 10,000, while Thomson in his late experiments makes it 694, or exactly 16 times lighter than oxigen gas, the specific gravity of which has been already stated to be 1111, to air as 1000: 100 cubic inches will therefore weigh 2.11 gr.

The only change effected on it by an addition of caloric, is an alteration of volume. By the abstraction of it, it cannot be made to lay aside the gaseous form, it is therefore considered a compound of the unknown base, hydrogen and caloric. It is not affected by light nor by electricity.

It is incapable of supporting combustion; a lighted taper put into it being instantly extinguished. If, for instance, a candle be thrust into a jar of the gas, with its mouth kept down, it is instantly extinguished, provided it is thrust a little way up into the jar, so as to get it beyond the influence of the air. It is also unfit for

respiration, as animals immersed in it speedily die. It does not, however, appear to be directly noxious to animal life, as it has been breathed for a considerable time with impunity, so that it seems unfit for respiration merely by excluding oxigen. Those who have breathed it have invariably found, that if the lungs be as nearly as possible exhausted of air, the respiration may be continued much longer than when it is received into them after an ordinary respiration. It has been observed also to change the tone of the voice, after being breathed for a short time.

The most remarkable property of hydrogen is its inflammability; when heated in contact with air, it burns with a reddish flame, the rapidity of the combustion depending on the method of holding the jar. If a jar of it be kept with the mouth down, and heat applied, the combustion is slow, because, owing to its lightness, it is confined, and thus comes slowly into contact with the air; but if the mouth be held up, the combustion is rapid, because, rising from the jar, it mixes with the atmosphere, and there is a sufficient supply of air to consume it. Though hydrogen is so easily inflamed, and burns with rapidity, yet we may set fire to a collection of it with perfect safety, provided we allow it to escape in a small stream. For this purpose, having filled a gasometer with it, on opening the stop-cock, and forcing out the gas, a flame may be applied. Or if, into a small phial, there is put a mixture which will furnish hydrogen, and a cock with a fine tube passing through it be put into the mouth, the gas will flow out, and may be kindled, and as the supply is kept up, there is a sufficient pressure to cause it to escape, and undergo combustion.

During the combustion of hydrogen in this way, if a glass tube be held over the flame, a sound is emitted, the loudness and nature of which depends on the size of the tube. For this purpose, having kindled the gas, a tube of about 2 feet in length, and about an inch in diameter, is held over the flame, but so as not to cover it completely. On raising or depressing it, the sound will

vary, but the tube must not be brought too far down, otherwise the gas is extinguished.

When hydrogen is mixed with air and heated, it explodes, but the explosion is by no means violent. This experiment is most easily performed by using a strong glass phial with a wide mouth, and having a double cork fitted to it, the one put into the mouth being perforated, and having a smaller one in it. Into this, inverted on a trough, is introduced 1 of hydrogen, and $2\frac{1}{2}$ of air, and, after removing the smaller cork, on the application of heat, (which may be done by applying a candle, or the flame of a piece of paper,) the mixture is exploded.

Hydrogen burns with much more splendour in oxigen gas; and to shew that this is the case, having filled a jar, open above and below, with oxigen, and placed it on a plate of water, set fire to a jet of the gas issuing from the pipe of a gas holder, and then plunge it into the upper aperture, having the tube passed through a cock that fits it. The moment that it is introduced, the flame will be observed to be more brilliant, and at the same time, the water will rise in the jar, proving that the oxigen is consumed.

That the inflammation of hydrogen is owing to its uniting with oxigen, may be shewn also in another way. Having filled a jar, the same as that used in the former experiment with hydrogen, allow a stream of oxigen gas to escape from a gas holder through a tube, passed through a cock that fits the upper aperture. Set fire to the hydrogen, and instantly insert the tube from which the oxigen is issuing, and the gas, which at first burned with a large flame, owing to its being in contact with air, now burns as if a stream of flame were issuing from the tube. This experiment must be conducted with great caution, because, if the oxigen be allowed to escape too quickly, the mixture will explode.

If, instead of setting fire to the hydrogen, in oxigen, they be mixed, and heated, they explode with great violence. The proper proportions are, two volumes of the former to one of the latter. This may be done in the ex-

ploding bottle already described, but here it is necessary to wrap a towel around it to prevent accidents, in the event of its bursting. If other proportions be used, there is one of the gases left uncombined, so that they will not in this way unite in any other proportions than those stated. If they be used with a large proportion of one of the gases, they do not explode; on the contrary, there is a slow combustion. Thus, if 9 of hydrogen, to 1 of oxigen, or the reverse proportions, be employed, the union goes on slowly. Hydrogen and oxigen may also be made to explode by electricity. Different forms of apparatus are employed. That now in common use is a glass tube, with wires passing through the sides of it, and terminating in the interior at about the distance of the 1-10th part of an inch from each other. Being filled with water or mercury, and inverted on a trough, the mixture of the gases is introduced, and by connecting the wires with a Leyden jar charged, (*see Electricity*,) the electricity may be transmitted through the mixture, which is instantly exploded. The jar in this experiment should not be above 1-4th full, to allow for the expansion occasioned during the explosion. For common purposes, the gases may be exploded in a bladder, using the adjustment described under the article Electricity.

In all of those instances in which hydrogen is burned, either in air or in oxigen, the hydrogen and oxigen unite and lay aside their gaseous form, generating a new compound, which is water.

Water.

Water was by the ancients considered one of the elements. Though, from some experiments performed about the year 1770, it was conjectured to be a compound, its nature was not known till 1781. This discovery was made about the same time by Mr Cavendish and Mr Watt, but we may consider the former as the discoverer

of its composition, for though the latter had formed a just opinion with respect to its nature, yet from some experiments of another chemist, he was inclined to doubt the accuracy of his conclusion.

Mr Cavendish set fire to 500,000 grains measure of hydrogen, mixed with rather more than twice their bulk of atmospheric air, the flame being made to pass through a glass cylinder, that the product might be collected. It was 135 grains by weight, of a transparent colourless fluid, destitute of taste and smell, and which, when evaporated, left no residuum. In another experiment, 19,500 measures of oxigen were exploded with 37,000 of hydrogen, by which 30 grains of a similar fluid were obtained, but in this last instance there were slight traces of nitric acid. In the same year, Lavoisier, who had been informed of the discoveries of Cavendish, performed similar experiments, and obtained similar results. In one, a very large quantity of the gases was consumed, the combustion being kept up for several days, and the product was also water.

In all these trials, it was found, when the gases were pure, and every source of fallacy avoided, that the weight of the fluid obtained, equalled exactly that of the substances consumed. In those instances in which nitric acid was detected in the product, its presence was easily accounted for by the union of the ingredients of the atmosphere, occasioned by the combustion, and when oxigen was used, its formation was explained in the same way, the oxigen obtained by the common process always containing a little nitrogen.

That hydrogen, by its combustion, forms water, is easily shewn. We have merely to set fire to a stream of gas, coming by a pipe from a gas holder, and allow it to burn in a globular, with a very small flame; the glass will soon become dim, from the deposition of moisture, and if the combustion be carried on sufficiently long, globules of a transparent colourless fluid trickle down the sides. In this instance, the hydrogen unites with the oxigen

of the atmosphere, water being the product of the action.

To render the proofs of the composition of this fluid still more satisfactory, it can be shewn that it contains oxigen and hydrogen. This can be done by electricity, or by exposing it to the action of a substance which will attract one of its ingredients, and set the other free. That generally employed for this purpose, is iron. It was at first observed by Bergman, that when iron filings are exposed to water, they acquire oxigen, and hydrogen is liberated. Lavoisier afterwards varied the experiment, by subjecting the fluid to the action of the metal at a red heat, and for this purpose, the apparatus required is very simple. If water be allowed to fall, drop by drop, into a red hot iron tube, or if it be passed in the state of steam through it, it is instantly decomposed, and resolved into its component parts. This is most easily done, by having an earthen tube, stuffed with shavings of iron, to one end of which a retort is fixed, the other terminating in a water trough, the tube being passed through a chauffer, *(see Cut, p.* 138.) On applying heat to the retort, the water, being converted to vapour, passes through the tube, and is decomposed, and an elastic fluid is given off, and may be collected in jars. That it is hydrogen, is shewn by its inflammability. If, after the experiment is finished, the iron be removed from the tube and weighed, it will be found heavier than before. That the additional weight is owing to the acquisition of oxigen, can be easily shewn by heating it with other bodies, as with charcoal, by which a substance is given off, that is known to contain oxigen. In this experiment, then, Lavoisier concluded, that the water was decomposed, that its oxigen united with the iron, and that its other ingredient, hydrogen, was set free. It is now well known that water is a compound of one volume of oxigen, and two of hydrogen, and it has been already mentioned, that their specific gravities are as 16 to 1, if so, they must unite by weight, 8 to 1. Again, the atom of

oxigen being 10, that of hydrogen is 1.25, and as water is a compound of an atom of each, the proportions of its ingredients are 1 to .125, that is, 8 to 1. In a 100 parts, then, they are 88.89 oxigen, to 11.11 hydrogen.

Water is a very important agent, not so much from the attraction which it exerts for other substances, as from its communicating to them that fluidity so necessary for their successful operation; and so little does it alter their affinities, that in most cases its action is entirely overlooked. When pure, it is destitute of taste, smell, and colour. Its specific gravity, and capacity for caloric, it has been already stated, are called 1000, being used as the standard of comparison. By the addition or abstraction of heat, it does not suffer any change, except in form, freezing at 32, and, under the usual pressure, boiling at 212.—*See Fluidity and Evaporation.* During congelation it often assumes a crystalline form. According to Dr Clarke, the crystal is rhomboidal; but according to Hauy and Delisle, it is octohedral. If the water be not pure, such as when it holds a salt in solution, the boiling point is higher, the degree depending on the salt, and the quantity dissolved; and in these cases, the temperature of the vapour is the same as that of the fluid from which it is formed. Hence a method of increasing the heat to be given to a body, by a water bath, or by steam, by dissolving a salt, as sea salt, nitre, or potash, in the water.

The action between water and atmospheric air is very important, as under it is included the consideration of what is called *spontaneous evaporation*, and the formation of rain, hail, snow, dew, and hoar frost.

We may here make the general remark, that water is capable of absorbing all aeriform fluids; but the quantity varies in different cases, and even in the same case under different circumstances.

All water which has been exposed to air contains it, but the quantity is very small; 100 inches containing only between one and two. Water may, in a great measure, be freed of its air by boiling, by keeping it under

an exhausted receiver, and also by freezing; but the whole of it is not by these means extracted.

Water absorbs oxigen gas. According to Dr Henry, 100 inches take up 3.5, and of hydrogen they absorb only 1.5. The circumstances which cause a difference in the quantity of gas absorbed, are temperature and pressure, the lower the former, the greater is the quantity taken up, till the fluid arrives at its congealing point, when the gas which it had imbibed is extricated. The greater the pressure, also, the larger is the quantity absorbed, and of course the less the pressure, the less the quantity; hence it is, that by the diminution of pressure, that with which the water had previously combined is evolved. It is asserted by Henry, with respect to the gases that are taken up sparingly by water, that it absorbs, of a gas condensed by an additional pressure, twice as much as it usually does; when condensed by two additional atmospheres, thrice as much is absorbed, and so on, the quantity being in proportion to the pressure. It has also been remarked by Henry and Dalton, that if water be agitated with a mixture of two gases, it does not take up the one of which it can absorb most, but both, the proportion being in the ratio of what it will absorb of each. They have also observed, that if it has previously taken up one gas, and be shaken along with another, a portion of the latter is absorbed, and of the other extricated.

The preceding remarks apply chiefly to the action of water with gases in general. We have now to make a few remarks on its action with atmospheric air. Almost all fluids, when exposed to the air, diminish in weight, and if for some time, they disappear; they are therefore said to disappear spontaneously, and the process is called *spontaneous evaporation*, to distinguish it from that produced by the agency of heat. Fluids disappear with different degrees of celerity. Water is evaporated slowly, spirit of wine quickly, and the volatile fluid ether, still more so. The lower the boiling point of the body, in general it evaporates more speedily. By increasing the sur-

face, also, the evaporation is accelerated; hence, when we wish to cause a fluid to disappear soon, it is put into a shallow vessel. A certain quantity of a substance can evaporate in a given bulk of air; and the less of it it previously contains, the quicker is the evaporation. When it has taken up as much as it can contain, it is then said to be *saturated*. By changing the air, therefore, exposed to the surface of the fluid, the evaporation is increased; hence the effect of wind in quickening evaporation, and in drying a moist body. By elevating also the temperature of the air, it can retain more of the fluid, and the quantity taken up increases in a greater ratio than the increase of temperature.

When the air, thus loaded with moisture, has its temperature cooled, as by exposing it to a cold object, part of that which it retains is deposited. Hence it is, that in crowded rooms, in which the air is loaded with watery vapour, given off chiefly by respiration, the windows and walls, which are colder than it, are always moist, and it is in this way that we can account for the formation of rain, hail, snow, dew, and hoar frost. When, by any means, the atmosphere of the higher regions has its temperature diminished, it loses in part the power of holding the watery vapour in solution, which is therefore set free. If the change be not great, rain may be the consequence; but if the reduction of temperature be considerable, snow or hail may fall. When the temperature of the atmosphere is more gradually reduced, dew or hoar frost may be produced. The deposition of dew is easily shewn, by exposing a bottle with cold water in a room; its sides very soon become moist. If the bottle be filled with a mixture of ice and salt, the moisture in the atmosphere is deposited on it, but it then assumes the form of hoar frost, being frozen by the cold of the mixture. In the same way, when the air immediately in contact with the ground, or with trees, or other objects, is by any means cooled, it deposits either dew or hoar frost, according to the temperature, *(See page 47.)*

It was at one time imagined, that when a fluid evapo-

rates spontaneously, it does not absorb caloric, as when evaporated by boiling,—an opinion now abandoned. It is well known, that during spontaneous evaporation, cold is generated; there must therefore be an absorption of caloric. It is, however, unnecessary to resume this subject. It has been already discussed under Evaporation, and Sources of Cold.

Owing to the evaporation constantly going on, from the surface of the water that surrounds this globe, the atmosphere always contains moisture; and as the quantity varies according to circumstances, it is evident that the specific gravity of the air must vary. When the air is mixed with watery vapour, it is enlarged; and as the vapour, bulk for bulk, is of less weight than air, it is evident that the specific gravity of moist air is less than that of dry air, and the same is the case with all other gases which are heavier than vapour. On the contrary, those which are specifically lighter, must, by admixture with it, become of greater specific gravity.

As the bulk, and consequent specific gravity, of gases are changed by containing moisture, it is necessary to attend to this circumstance when experimenting on them. They must either be rendered dry, or allowance must be made, according to the quantity of vapour they contain.

The gases are easily rendered dry, provided they are collected over mercury. For this purpose, we have merely to introduce into the jar, a substance which has an affinity for water, and which will not act chemically with the gas, as well-dried lime, carbonate of potass, or muriate of lime, and leave it there for some hours. If the gas cannot be dried, it may be reduced to its proper bulk by calculation. If it has been prepared over water, it must be saturated with moisture, and as *the same bulk of all gases contains, when at similar temperatures, the same quantity of vapour*, we can easily, from the tables of the elastic force of vapours at different temperatures, find how much is contained in the gas, and consequently the expansion it has suffered. The most accurate table of the force of aqueous vapour, at different temperatures,

is that given by Mr Dalton, *(see Appendix.)* Suppose, then, we have 100 volumes of air at 60, saturated with moisture, the elastic force of the vapour in it, is, according to the table, .524 of an inch; then to reduce the moist air to the volume it would occupy when dry, multiply the volume of the moist air by the height of the barometer, (suppose 30,) minus the elastic force of the vapour, and divide by the height of the barometer.

$$100 \times (30 - .524) = \frac{2947.6}{30} = 98.25$$

So that 100 of moist air at 60, would be, when dry, 98.25.

As the air of the atmosphere is constantly loaded with moisture, it is of the utmost importance to be able to ascertain how much it contains. This subject is called *Hygrometry*, and the instruments by which the quantity of moisture is ascertained, are termed *Hygrometers*. Our feelings are very imperfect indicators of the state of the atmosphere with regard to dryness; we have therefore recourse to other means.

1*st*. To find the quantity of moisture which a certain bulk of the air will take up; and having found this, we have merely to subtract it from what we know the air will contain when saturated, at the temperature at which the experiment is performed. One of the means of doing this, is by Mr Leslie's *Atmometer*, (ατμος, *moisture.*)

It consists of a glass tube, to which a hollow porous earthen-ware ball is fixed, there being divisions on the former, corresponding with the surface of the latter. The ball and tube being filled with water, by exposing it to a certain bulk of air, the fluid will evaporate, and of course fall in the tube, so that the quantity lost is known; and by subtracting this from what the air would hold when saturated, that previously in it is found out.

2*d*. The cold produced by evaporation, is another method of finding the quantity of moisture; and for a means of doing this, we are indebted also to Mr Leslie. His hygrometer is merely a differential thermometer, with one ball covered with silk of the same colour as the

glass of the other. By applying water to the former, if the air be very dry, the evaporation, and consequent reduction of temperature, will be great; whereas, if it be moist, suppose it saturated, there will be no evaporation, and of course no change in the temperature. The cold generated, is measured by a scale adapted to the tube, the degrees corresponding with the state of the atmosphere.

It was at first supposed, that this instrument would be of little use, as evaporation depends so much on the supply of air; it was therefore imagined, that the cold would be greater in windy than during calm weather, even though on both occasions it had the same quantity of moisture. Mr Leslie has, however, shewn that this is not the case, the cold produced being the same, whether the instrument be exposed on a calm or windy day. The cause of this seems to be, that the first portion of vapour formed, abstracts caloric from the air within the ball, and generates cold; but the moment that it is produced, it is carried off by the wind, by which air is supplied, and more vapour formed; but as the temperature of the air without, is higher than that within, it is from it that the caloric is now taken, and by which the vapour is produced, so that though the evaporation is accelerated, there is no farther reduction.

3d. There are many bodies which have a powerful attraction for water, consequently by exposing them to air they unite with its moisture, and become heavier, so that by weighing them, we have an indication of the state of the atmosphere with regard to dryness. Should the substance not change its form by the absorption, instead of weighing it, it is attached to the end of a beam, to the opposite end of which a counterpoise is fixed, and the upright stem is made to move along a scale on which there are degrees corresponding to the state of the atmosphere. The substances employed in the first of these ways are oil of vitriol, potassa, carbonate of potassa, muriate of lime, and some others. Those used in the last

way, are sponge, Paris plaster, or a piece of bibulous paper.

4th. The next, and perhaps the most accurate mode, is by the change in length which some bodies experience by becoming moist. Animal substances have the property of absorbing moisture, and becoming longer, and of course when they again give it off, they are shortened, so that an indication is thus afforded of the state of the atmosphere. Saussure's hygrometer is of this kind. It consists of a human hair, one end of which is fixed, the other is put round a pulley, and has an index fixed to it, which moves on a scale, so that the slightest change in its length is indicated. De Luc, instead of a hair, proposed a piece of whale-bone cut across the grain.

In adapting a scale to these different instruments, one end must correspond with extreme dryness, the other with extreme moisture, the former of which is ascertained by placing it in a jar at a certain temperature, say 50, along with some substance that will absorb the whole of the moisture, so as to render the air dry; the point at which the index stands is extreme dryness. If the instrument be now placed under a bell jar, resting on a plate of water, of course at 50, the air will become saturated, and the index will point to extreme moisture. The space between these is divided into degrees, which are quite arbitrary, in general into 100.

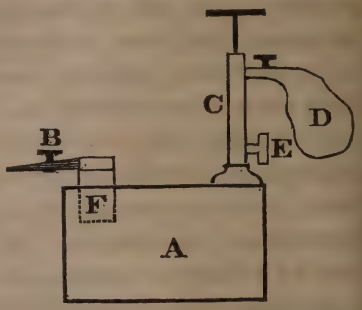
It is not yet determined in what state the vapour exists in the atmosphere. Some suppose that it is merely mechanically blended with it, while others assert that it is in chemical union. The strongest argument brought forward by the supporters of them echanical opinion, is, that water passes into vapour *in vacuo*, consequently when all action of the air is removed. Thus, if a drop of water be allowed to ascend to the surface of the mercury in a barometer, it instantly assumes the state of vapour, and depresses the fluid. Another strong argument in favour of this doctrine, is, that the same bulk of all gases, contains at similar temperatures the same quantity of moisture; were it not merely mechanical action,

it is supposed that the quantity would vary. On the other hand it must be admitted, that there are strong arguments on the side of the chemical opinion, and perhaps the strongest of these is the power which the atmosphere has of depriving bodies of the water they contain. Thus, many salts, when exposed to air, lose no less than half of their weight, and the rapidity with which the change takes place, depends on the state of the atmosphere; indeed, if it be moist, there is no change at all. Now in these cases it is known, that the water is held in the salts by affinity; it seems natural to suppose, that if it be taken from them, it must be by one that is more powerful.

Hydrogen gas is always procured by the decomposition of water. One method of obtaining it has been already mentioned, when giving the analytic proofs of the composition of this fluid, p. 189. For procuring it on a small scale, a much more simple process is followed, the water being decomposed by iron, aided by an acid. For this purpose, put into a retort one oz. weight of iron filings, (or if the gas be required pure, one of zinc,) then pour in four of water, and immediately afterwards one of oil of vitriol. There is an instant effervescence, and disengagement of hydrogen gas; the water undergoing decomposition, gives its oxigen to the metal to convert it into an oxid, which, uniting with the acid, forms a salt, and is left in solution in the retort; the other ingredient of the fluid, the hydrogen, is set free.

It has been already said, that when hydrogen and oxigen are mixed in proper proportions, and heat applied, they explode. If, after being mixed, they be allowed to flow in a small stream, and kindled, they excite a very intense heat, perhaps the most intense we have yet been able to produce. This constitutes what is called the *oxihydrogen blow-pipe*. When the gases were first used for this purpose, they were kept in separate vessels, and forced out by a column of water, a pipe proceeding from each, and terminating by a common aperture. An instrument has been lately constructed by Mr Newman, into which the mixture is forced by a condensing syringe,

and from which it again issues when the stop-cock is opened. It consists of a strong copper box A, to which there is adapted a stop-cock B, terminated by a very fine aperture. C is the condensing syringe, by which the gases are thrown from the bladder D, into the box. When full, having shut the cock E, the syringe is removed, and on opening the cock B, the gas issues with great force, and may be kindled.



When this apparatus was first used, dangerous explosions often happened, owing to the flame rushing into the box, and setting fire to the gases; but this is now prevented by what are called safety tubes, which are merely a number of very fine tubes, or, which answers equally well, several folds of fine wire gauze, both of which allow the gas to escape, but prevent the admission of the flame. These are placed in a small box attached to the cock F. There is occasionally also a small reservoir with oil, through which the gas passes, and which, should the flame by any means get through the gauze, puts a stop to its progress inwards. When a piece of iron placed on charcoal is exposed to the flame of the gases, it is very soon melted, and thrown about in beautiful sparks. The heat excited is even sufficient to melt the earths. Thus, if a piece of tobacco pipe is held at the point of the flame, it is instantly melted; and if this be done in the dark, the light is very intense, so much so that it is impossible to bear it for any time. Though by this apparatus we can act only on small objects, yet it affords an excellent method of ascertaining the effects of an intense heat on different bodies. These will be enumerated, when giving the chemical history of those that have been subjected to its action. If, instead of the tobacco pipe, a piece of lime prepared by heating chalk to redness, be used, and placed in the centre between four or five jets

of the flame, the light produced is astonishingly brilliant, so much so, that it is seen in a dark night at the distance of many miles, and hence the use to which it has lately been put in carrying on trigonometric surveys.

Dr Skidmore has lately found that the flame of the oxi-hydrogen blow-pipe, may even be kept up under water, provided the tube from which it issues be slowly introduced, and kept perpendicular. The brilliancy is the same, but the flame assumes a globular form. If a piece of wood be held near it, it gives off sparks, and metals are easily ignited.

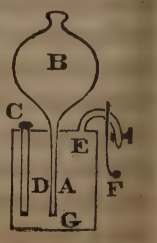
Hydrogen, from its extreme lightness, is employed for filling balloons. A balloon is merely an air-tight bag, made of some very light material, so that, when filled with hydrogen, it is lighter than its own bulk of air, consequently, when left to itself, it rises, just as a cork would do from the bottom of a jar of water. An easy method of shewing the ascent of a body filled with this gas, is the familiar instance of a soap bubble, which ascends when let off from a tobacco-pipe, attached to a tube coming from a gas-holder of hydrogen, the soap bubble being filled with it, instead of the air from the lungs, as in the common method of forming it. Balloons are made of oiled silk, rendered air-tight by being covered with varnish. That commonly employed is Indian rubber, dissolved in oil of turpentine. As a sphere presents less extent of surface in proportion to its contents than any other figure, it is of course the best for a balloon; but they are seldom made of this form; they are in general of a pear shape, the point being kept down. The hydrogen is prepared from a mixture of oil of vitriol and water, with pieces of old iron. These are mixed in barrels, made air-tight by clay, from which there proceed tubes, that join with the mouth of the balloon.

Hydrogen gas is now much employed as a means of procuring a light. This was formerly done by electricity, but the apparatus, besides being costly, is difficult to manage, and apt to get out of repair. A much more easily managed and less expensive method, is by the action of

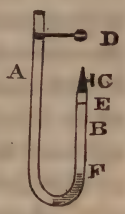
platinum. Platinum is soluble in aqua regia, and by the addition of sal ammoniac to the solution, a brown powder is precipitated, which, when subjected to a red heat, affords metallic platinum in a spongy state. *See Platinum.*

Doboreigner of Jena, made the important discovery, (An. de Ch. et de Ph. xxiv.) that when this spongy matter is exposed to the action of a stream of hydrogen gas, it absorbs it with great rapidity, becomes red hot, and at last, provided air is present, sets the gas on fire. If the sponge fixed to the end of a wire, be introduced into a bladder, or strong phial, full of a mixture of 2 of hydrogen and 1 of oxigen, it soon becomes incandescent, and causes explosion. If the gases be not in proper proportion, as when there is a large excess of one, or when the hydrogen is mixed with air, there is no explosion, but a gradual diminution, owing to their union, and consequent formation of water. Doboreigner has also shewn, that the platinum acts equally well for causing the gases to unite, if it be mixed with clay. For this purpose it is made into small balls, with an equal weight of moistened clay, and which are afterwards dried by a slight heat. To shew the action of these, having filled a jar with a mixture of air, and a little hydrogen, over mercury, the ball is introduced, and as it rests on the surface, it causes the condensation of the gases, which is shewn by the rise of the fluid. The use to which this is applied in eudiometry, will be immediately noticed.

Since hydrogen is thus so easily inflamed, it affords a convenient method of procuring a light. Different forms of apparatus are employed; perhaps that recommended some time ago by Gay Lussac, for keeping a store of hydrogen, is the best. It consists of two vessels, A and B. A is a bottle with three apertures; into C is placed a stopper, to which a rod of zinc, D, is fixed. From E there proceeds a tube, with a stopcock, having a very fine opening, placed immediately opposite a little box, F, containing the platinum. The vessel B, terminates by a tube, G,



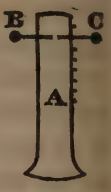
which passes nearly to the bottom of A. Having filled A with a mixture of oil of vitriol and water, 1 to 8, the zinc rod is to be introduced, by which the water is decomposed, and hydrogen is disengaged. As it rises to the top of A, it depresses the fluid in it, and makes it ascend into B; but the moment it gets below the end of the rod D, the action stops, while, at the same time, the mouth of the pipe G being below the fluid, there is no escape of gas. On opening the stop-cock, the gas rushes out, and coming on the platinum, is kindled; the fluid at the same time falls, and getting on the zinc, generates more hydrogen, so that we have always a constant store of gas, subject to the pressure of a column of fluid, by which it may be forced out. Another, but simpler form of the hydrogen lamp, is merely a bent tube, A B, with a stop-cock, C, having the spongy platinum, D, placed opposite it. Having put in the acid mixture as far as E, a piece of zinc, F, is thrown into the limb B, being allowed to rest on a piece of glass rod, and the stop-cock is then adapted. Hydrogen is generated, and rises in B, depressing the fluid in it, and making it rise in A; but when it gets below the zinc, the action ceases, and the gas is prevented from escaping, by the bent part of the tube being filled with fluid. On opening the cock, gas escapes, and is kindled, the fluid falls in A, and rises in B, and being again acted on by the zinc, affords more hydrogen; so that we can have always a supply of gas, subject to the pressure of water, by which it is expelled when the stop-cock is opened.



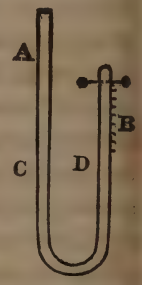
The distance at which the platinum must be placed, in these instruments, depends on the pressure, and the size of the aperture of the cock; it must therefore be found by trial. In general, half an inch is sufficient.

It has been already mentioned, that a mixture of oxigen and hydrogen is exploded by electricity, and hence the application of this to eudiometric purposes, with the view of ascertaining the quantity of either, that

exists in any gaseous mixture. For this purpose, a strong graduated glass jar A, is used, through the sides of which there pass wires, B C, terminating at the distance of the one-tenth of an inch from each other. Having filled it with mercury, the gas is to be introduced so as to occupy only about $\frac{1}{4}$ part of it, so as to allow room for expansion during the explosion. The wires are then connected with a charged Leyden jar, and a shock passed through them, *(see Electricity,)* and the rise of the mercury occasioned by the condensation, indicates the quantity of gas in the mixture, attending to the usual precautions with respect to temperature and pressure, *(see* p. 167.)



Another, and more convenient form of apparatus, has been recommended by Dr Ure. It consists of a bent tube, A B, open at A, and shut at B, which is graduated, and has wires passing into it, in the same way as in the other. Having filled it with mercury, and then inserted the gas, so as to occupy a few inches only of B, leaving mercury in the bent part, say from C to D, so that the remainder of A shall be full of air; placing the thumb on the open end, an electric spark is passed through the wires, by which the gases are exploded; and though, during the explosion, there is a considerable expansion, the mercury is prevented from escaping at the open end; of course the moment the condensation occurs, the mercury rises in the opposite limb.



When we wish then to ascertain the quantity of oxigen in a gas, it is mixed with hydrogen, and fired, and as 2 of the latter unite with 1 of the former, we allow 1-3d of the diminution for oxigen. If, on the contrary, the quantity of hydrogen is to be known, the gas is mixed with oxigen, and fired, and 2-3ds of the diminution allowed for it.

This method of finding the proportion of oxigen, or hydrogen, though extremely accurate, is subject to this objection, that when they are in a great state of dilution,

the electricity does not produce explosion; it is necessary, therefore, to add along with the gas, some of that already in the mixture, and after deducting from the whole diminution, that occasioned by the gas added, the remainder must be allowed for that produced by what previously existed in it.

It has been already mentioned, that spongy platinum causes the union of oxigen and hydrogen. This is now also applied to eudiometric purposes, and is likely to supersede the use of electricity, not only because it is more easily conducted, but because it acts on the gases when in a great state of dilution. The method of conducting this experiment is extremely simple. A graduated jar being filled over mercury, to a certain depth, with the gas to be analyzed, the other is introduced, and a ball of platinum and clay allowed to rise to the surface; the union of oxigen and hydrogen goes on slowly, and when completed, 2-3ds must be allowed for hydrogen, if it existed in the mixture, or 1-3d for oxigen. It has been found, also, by Dobereigner, that the spongy platinum will act on the gases, confined by water, so that the experiment may be performed over this fluid. This is most easily done by forming the sponge in the tube; and for this purpose, the precipitate placed at the shut end, is heated by a spirit lamp, and is thus decomposed, and adheres to the sides. The tube being filled with water on a trough, has the gas introduced, and condensation goes on in the usual way. (Ed. Phil. Journ. xi.)

The ignition of platinum by hydrogen, has not yet been satisfactorily accounted for. Dobereigner has supposed it to be owing to electricity, the hydrogen and platinum forming an electric circuit; a supposition not supported by experiment.

Peroxid of Hydrogen.

According to Thenard, (An. de Chim. viii.—An. of Phil. vi.) oxigen and hydrogen unite in other pro-

portions than those constituting water, and form a fluid possessed of very remarkable properties, which has been called deutoxid, or peroxid of hydrogen. It is prepared by a very complicated process, in which substances are used, the properties of which have not yet been described, (*see Baryta.*)

Peroxid of hydrogen is a transparent colourless fluid, which, when it touches the skin, occasions pain succeeded by inflammation. Its specific gravity is 1452; when heated, it gives off oxigen gas, the disengagement commencing at about 60, and hence the necessity of keeping it below this. It is decomposed by many of the metals and their compounds. Thus, when thrown on filings of lead, silver, or gold, oxigen is disengaged. A few of the metals, as arsenic, in decomposing it, unite with its oxigen. Some of the compounds of the metals, and oxigen, cause the excess of oxigen to be set free, without themselves undergoing any change, while others at the same time give off their own oxigen.

As the oxigen is easily expelled from this compound, and by which it is converted to water, the proportions of its ingredients are thus discovered; but as during the expulsion there is a considerable explosion, it is necessary to dilute it. In analyzing it, Thenard mixed a certain weight of it with about 20 of water, and heated it cautiously, by which the whole of the oxigen above that necessary for the conversion of the hydrogen into water, was driven off and collected. In this way he found it to contain exactly twice as much as exists in water, so that if we consider the latter as composed of 1 of hydrogen to 8 of oxigen, the oxigenized fluid will contain 1 to 16, and if so, it must have 1 atom of the one to 2 of the other, and its atomic weight will therefore be 21.25.

Hydrogen exists in all animal and vegetable matter, and is given off by them during their putrefaction. Hence it is found in pits, in marshy situations, and over stagnant pools. In the present state of the science, it must be considered an elementary body.

SECTION III.

SIMPLE ACIDIFIABLE BODIES.

NITROGEN, OR AZOTE.

It has been already mentioned, that the air of the atmosphere contains, besides oxigen, a gas possessed of very different properties. It is *Nitrogen*, so called because it enters into the composition of nitre and nitric acid, a name given it instead of *Azote*, by which it was usually known, and derived from the Greek α, *privative*, and ζωή, *life*, as being destructive of animal life.

It is a transparent and colourless gas, destitute of taste and smell. It is lighter than atmospheric air; but its specific gravity has been variously stated. According to Biot and Arrago it is 969, while Dr Thomson makes it 972.2, which is now generally considered to be correct; 100 inches weighing at temp. 60, and bar. 30, 29.65 gr. Its atom is 17.5.

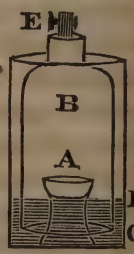
Caloric causes no change on it except that of volume. It is not affected by light. Its distinguishing feature is its not supporting combustion, as is shewn by putting into it a lighted candle, or by placing a jar of it over a piece of burning phosphorus, by which both are extinguished. A beautiful illustration of the influence of oxigen and nitrogen over combustion, is shewn by filling a vase with each, and plunging into the latter a candle with a long wick, by which it is instantly extinguished; but

on removing it, and putting it into the former, it is rekindled, and burns with a bright flame. For the success of this experiment, however, it is necessary that there be a part of the wick red before it is put into the oxigen.

Nitrogen is sparingly absorbed by water, 100 inches taking up only about 1.5. It unites with oxigen, and forms some very important substances, the first of which is the

Air of the Atmosphere.

The proportions in which oxigen and nitrogen form air, are discovered by exposing bodies to it, which will deprive it of one of its ingredients, and leave the other; that almost always taken away being oxigen. The different modes practised will be noticed in their due places, when describing the properties of the substances used. One method may, however, be here mentioned, because it will so far not only prove the composition of the atmosphere, but also point out one of the means of procuring nitrogen gas. For this purpose, a mixture of 1 of flowers of sulphur, and 3 of iron filings moistened, is put into a dish, A, over which a bell jar, B, is placed, resting below in a vessel of water, C. On leaving it there for some hours, the oxigen of the air in the jar unites with the sulphur and iron, and the water rises to supply its place, say to D. What is left is nitrogen; and that it is so, is proved by putting into it a lighted candle, which is instantly extinguished. If we wish to expel the gas from B, we have merely to adapt a tube to the stop-cock, E, and pour water into C, which, when the stop-cock is opened, forces out the gas; so that, by putting the tube under a jar in a water-trough, it may be collected.



Scheele, in his first attempts to prove the composition of the atmosphere, concluded that its ingredients were in the ratio of 73 of nitrogen, to 27 of oxigen by volume. Priestley, on the contrary, asserted, that the latter varied

from 20 to 25, while others made it so high as 28. The later experiments of Davy, Dalton, Gay Lussac, and others, have shewn, however, the inaccuracy of these conclusions; they agree in making the oxigen to be 21, or, taking the average of a number of experiments, 21.5, the nitrogen of course being 78.5. It was at one time supposed, also, that the proportions of the ingredients occasionally varied. Ingenhouse, who first made experiments on this subject, concluded, that at sea the air contained more oxigen than over land, while near marshy situations it had less than usual. Saussure, Humboldt, and others, have likewise asserted, that air brought from the higher regions, has less oxigen than that near the earth immediately below. The later experiments of Cavendish, Dalton, Davy, Gay Lussac, and others, have, however, proved the inaccuracy of these statements, not only with respect to the proportions of the ingredients, but also to their varying; they have found, as already mentioned, that the oxigen has in general been greatly overrated. According to them it is 21, or to take the average of a number of trials, 21.5 to 78.5 of nitrogen, and this, they have stated, is the quantity in all situations; experiments performed on it in different places, and from different heights, always giving the same proportions. Though the ingredients have thus been fixed, by the above-mentioned chemists, at 21.5 oxigen to 78.5 nitrogen, Dr Thomson has lately asserted that they are 20 to 80, which he has proved by experiments performed with very great care, by means of electricity, (First Princ.) If this statement be correct, the general law of Gay Lussac, with respect to the union of gases in ratios, the most simple, will hold true in this as in other instances; and that these are really the proportions, seems confirmed by calculation founded on the specific gravity of the gases. That of nitrogen is 972.2, and of oxigen 1111.1.

$$\text{Now, } \frac{972.2 \times 4 + 1111.1}{5} = 999.9,$$

as near 1000 as can be expected.

Though the atmosphere is considered as composed of

oxigen and nitrogen, other substances exist in it, of which the principal are watery vapour, and the elastic fluid called carbonic acid. These must, however, be considered adventitious, the former being derived from the evaporation constantly going on from the surface of the water; the latter a product of respiration and combustion. Its quantity varies from 1 in the 100, to 1 in the 1000, and of course, according to its proportion, so must be that of the oxigen and nitrogen; but though this is the case, the relative quantities of the latter to each other is always the same.

Though carbonic acid is stated as existing in the atmosphere, Vogel has lately asserted, (An. of Phil. N. S. ix.) that that over the ocean does not contain any; if so, the proportion of its ingredients, leaving out the watery vapour, are 20 oxigen to 80 nitrogen.

With respect to the relation which the ingredients of the atmosphere bear to each other, some suppose that they are merely mixed, while others assert that they are in chemical union. Those who espouse the latter doctrine, argue, that if they were in a state of mixture, they would separate, and each would occupy the situation allotted to it by its specific gravity; which, however, is not the case, the air being of uniform composition throughout. Besides, it is well known that affinity does exist between them; for they can be made to enter into union. On the contrary, the supporters of the mechanical doctrine assert, that if they do combine when they are presented to each other, in the proportions constituting air, they ought to shew marks of action, and the product ought to have properties different from those of its ingredients; neither of which is the case. Mr Dalton, who espouses this side of the question, has formed an hypothesis, by which he endeavours to explain why the gases do not separate, and which he has applied, not only to the atmosphere, but to all other mixture of aeriform bodies, whether gases or vapours. The particles of a pure elastic fluid, are, according to him, globular; and as they are all in any small given

volume subject to the same pressure, they will be of the same bulk, and will present the appearance of a pile of balls. They are, he conceives, composed of an exceedingly small central atom of solid matter, surrounded by an atmosphere of heat, of great density next the centre, but gradually becoming rarer. An elastic fluid expands the moment the pressure is diminished; the particles must therefore, he says, repel each other. When, then, gases which do not act chemically are mixed, Mr Dalton supposes that the particles of the one are non-elastic, or repulsive with respect to those of the other; consequently, each will act with its own elasticity or repulsion, and diffuse itself throughout the jar. As the one neither attracts nor repels the other, there is no reason why they should occupy different places, according to their specific gravity; so that the particles of the one will go into the interstices of the other.

This opinion of Dalton has drawn forth the animadversions of several eminent chemists; but for the fuller illustration of this subject, the reader is referred to Dalton's System of Chemical Philosophy.

Air is necessary for combustion and respiration. A candle will not burn *in vacuo*, or if it be kept in a confined quantity of it, the combustion soon ceases. Thus, if a jar open above and below, but having a cork fitted accurately to the upper aperture, be placed over a candle standing in a plate of water, the flame very soon disappears; and that there is a consumption of part of the air, is shewn by the rise of the water in the jar; and that it is the oxigen that is removed, is proved by introducing a lighted taper into the residual gas, which is instantly extinguished.

It is remarkable, however, that though atmospheric air supports combustion, and which it does from its containing oxigen, it loses this power long before the whole of this gas is consumed. It is well known, that a lamp with oil will burn in air in which a candle has been extinguished, and this is still more beautifully illustrated by an experiment of Davy, (Davy on Flame,) in which

he kept a candle in a bottle till it was extinguished. On removing it, the mouth was covered, and there was afterwards introduced a stream of hydrogen, inflamed, which continued to burn for some time. On removing the pipe, a sulphur match was found to burn, and even after it a piece of phosphorus, when heated in the residual gas, took fire, and its combustion continued, though by no means with the same splendour as in air. These effects seem to be occasioned by the admixture of the product of the combustion with the air, and hence they vary according to the nature of the inflammable body.

Air is also essential for respiration. If any one of the higher classes of animals be confined in an exhausted receiver, it speedily expires. A renewal of it is also necessary; for if the animal be kept in a confined quantity of it, and unless it is changed, life is soon extinguished, owing to a total alteration of properties, and that it is so is easily proved. We have merely to mount a jar on a water-trough, and by means of a bent tube, fill it with air from the lungs. On putting a lighted candle into it, it is instantly extinguished, so that that part which supports combustion is consumed. The nature of the changes that take place during combustion and respiration, will be detailed when describing the properties of inflammables, and when treating of blood. The pressure of the atmosphere, and the purposes it serves in spontaneous evaporation, have been already considered under *atmosphere* and *water*, pp. 165. 190.

Protoxid of Nitrogen, or Nitrous Oxid.

This elastic fluid is not prepared by the direct combination of its ingredients; we are obliged, therefore, to have recourse to the decomposition of compounds containing them. The substance from which it is always obtained is the salt called nitrate of ammonia, which is a compound of nitric acid and ammonia, the former containing oxigen and nitrogen, the latter hydrogen and nitrogen, and which, by the application of heat, are

made to enter into a new state of union, and generate two new compounds, water and nitrous oxid, *(see Nitrate of Ammonia.)*

Nitrous oxid was discovered by Priestley in 1778, who gave it the name of Dephlogisticated Nitrous Air. The associated Dutch chemists examined its nature, and shewed that it contains oxigen and nitrogen, but we are indebted to Sir H. Davy for the fullest account of its properties, which he has published in his "Researches into the nature of *nitrous oxid*," the name given to it by him.

It is a transparent and colourless gas, hence, of course, invisible. Its specific gravity is 1527, 100 cubic inches, weighing 45.5 gr. It has a sweet taste, and a faint peculiar odour. Mr Faraday has succeeded, by subjecting it to strong pressure, in condensing it into a transparent colourless fluid, which was so volatile, that the heat of the hand made it evaporate, even though kept under the pressure at which it was produced. It remained liquid at — 10 F. When the tube in which it had been condensed was broken, it instantly flew off in vapour.

By exposing nitrous oxid to a high temperature, as when it is passed through a red hot tube, or by transmitting electric sparks through it, it is decomposed and converted into nitric acid and atmospheric air, both of which contain oxigen and nitrogen, the former having a larger, the latter a smaller proportion of oxigen than exists in nitrous oxid. It is evident, therefore, that one part must have taken oxigen from the other, that gaining it becoming the acid, the other losing it, the atmospheric air.

Light does not exert any change on it. By subjecting it to the action of many other bodies, the properties of which have not yet been described, its composition, and the proportions of its ingredients, have been discovered. From the experiments of Davy, and of Gay Lussac and Thenard, it is known to be composed of two volumes of nitrogen, and one of oxigen, which together make two

volumes; and that this is the case is proved by its action with hydrogen. When mixed with it, and heat is applied, or when an electric spark is passed through it, it explodes. The proper proportions are two of each, and the products are water and nitrogen, equal in bulk to the oxid. It is evident from this, that it must contain its own volume of nitrogen; and again, as the whole of the hydrogen has formed water, with the oxigen existing in it, it must contain half its bulk of oxigen, because 2 of hydrogen require 1 of oxigen to form water. Nitrous oxid is therefore composed of two of nitrogen, and one of oxigen condensed into two. If so, its component parts are $972.2 \times 2 = 1944.4$, to 1111.1,

and as $1944.4 : 1111.1 :: 17.5 : 10.$

So that it is composed of

1 atom of nitrogen,	17.5
1 atom of oxigen,	10.
and its atomic weight is	27.5

This also shews that the atom of nitrogen is represented by 2 volumes, the oxid containing 1 of oxigen and 2 of nitrogen. As it is composed of two volumes of nitrogen, and one of oxigen condensed into two, its specific gravity is

$$\frac{972 \times 2 + 1111}{2} = 1752;$$

which is that given it by Thomson.

Nitrous oxid has no action with oxigen, with nitrogen, or with air. It is capable of supporting combustion. If a candle recently extinguished, but with part of the wick still red, be put into a jar of it, it is rekindled, and then burns with a bright flame. A distinguishing feature of the gas, is its action with sulphur. If a match, just when kindled, be put into it, it is extinguished; but if the combustion be allowed to become lively before it is immersed in it, it then burns with a bright white flame, with a rose red tinge around the edge.

Nitrous oxid is respirable; it is, however, unfit for the support of life. Priestley and others have shewn, that

animals confined in it soon expired. Davy found, that the larger warm-blooded ones died in five or six minutes, and the smaller ones in two minutes. Those of the amphibious class lived longer, but insects were killed almost the moment they were introduced. Fish kept in water impregnated with it, died in a quarter of an hour.

Its effects on the human system are remarkable. They were first discovered by Davy, who had the boldness to breathe it undiluted. It is a powerful stimulant, producing great excitement both of body and mind. Soon after breathing it, a particular sensation is felt, attended with a pleasurable thrilling in the chest and extremities; the objects around become dazzling, and the hearing is rendered acute. As the respiration is continued, these sensations increase, accompanied, in general, with a propensity to muscular motion and violent laughter, and the desire to continue the respiration becomes so strong, that the person lays hold of the pipe from which he breathes it, and makes resistance to any attempt made to deprive him of it; there is no danger, however, of his taking too much, for the muscles of the mouth becoming no longer able to shut on the pipe, he either allows it to drop, or he breathes only atmospheric air. After it has been breathed for some time, the lips become pale or livid, and the individual, in general, loses all recollection of what has happened. The effects vary, however, in different persons, and even in the same individual at different times. In some the intellectual faculties only are affected, while in others there is a propensity to muscular motion, as dancing, leaping, or running. It has occasionally happened, however, that nitrous oxid has been breathed without causing any peculiar effects, and which has given rise to the idea that imagination has a great share in producing those mentioned; but this has now been put beyond doubt, repeated attempts having been made to deceive the people, as by substituting air for it, or by not informing the person of the effects it was likely to induce. It is remarkable, that in many cases the individual is aware that he is be-

having strangely, but the propensity is so strong that he cannot refrain from it. In general, the effects cease in the course of five or six minutes, and what is remarkable, they are not succeeded by depression, which is the case with other stimuli, on the contrary, a degree of exhilaration continues for some time. The quantity of gas required varies in different persons, and even in the same individual at different times. From 4 to 10 quarts may be respired, and its effects, in general, appear in the course of about a minute; but as he becomes accustomed to it, a larger quantity is necessary. Sir H. Davy states that he has breathed it for 4½ minutes.

The method of respiring it is very simple. A bladder or oiled silk bag, furnished with a stop-cock, is filled with it, and having emptied the lungs as much as possible, the pipe is put into the mouth, and the nitrous oxid is drawn in, taking care to stop the nostrils; to prevent the admission of atmospheric air. Having kept the gas in the lungs for a short time, it may either be thrown away, or expired into the bladder, and which is preferable, because its properties are not completely destroyed by one inspiration. In this way it may be drawn from the bladder into the lungs, and from them thrown again into the bladder, till the effects are produced.

It has been ascertained, that after the respiration has been kept up for some time, the gas disappears, and nitrogen is left. When exposed to blood, it seems also to be absorbed, and to have its place supplied by nitrogen; but how it acts in producing its singular effects has not been ascertained.

Nitrous oxid is easily absorbed by water, which, at a natural temperature and pressure, will take up nearly its own bulk of it. Though this is the case, we may prepare it with a water trough, because, though it absorbs it in considerable quantity, yet the absorption goes on slowly. The solution has a sweetish taste, and will, on boiling, give off the oxid unchanged in its properties.

Peroxid of Nitrogen, or Nitric Oxid.

This was first mentioned by Hales, but Priestley may be considered the discoverer of it, at least we are indebted to him for the first account of it. He gave it the name of *Nitrous Air*, and it was afterwards called *Nitrous Gas*, terms which have given way to those of nitric oxid, and peroxid of nitrogen.

Nitric oxid is a transparent colourless gas, of course invisible. Its specific gravity has been differently stated; according to Kirwan, it is 1190, to Davy, 1102, while Dr Thomson considers it to be 1041, which it will be immediately shewn is correct; if so, 100 cubic inches will weigh 31.7 grains.

When subjected to the action of substances having a powerful attraction for oxigen, it is decomposed, nitrogen gas is set at liberty, and a compound of oxigen and the other body is formed. The action with charcoal is the most simple, and most satisfactory. Charcoal, it may be here remarked, unites with oxigen, and forms a gas called carbonic acid, containing exactly its own volume of oxigen. Now, if charcoal in a state of combustion be introduced into 4 volumes of nitric oxid, 2 volumes of nitrogen, and 2 volumes of the compound of carbon and oxigen, are formed, and which, it has been said, contains its own volume of the latter. From this it is evident, that the component parts of 4 volumes of nitric oxid are, 2 volumes of oxigen and 2 of nitrogen, united without condensation. Nitrous oxid, it has been already said, (p. 212.) contains one of oxigen, and two of nitrogen, so that it has only half the quantity of oxigen that exists in the peroxid.

Since nitric oxid contains equal volumes of nitrogen and oxigen, the proportions by weight must be as their specific gravities; that is, as 972 to 1111,

and as 972 : 1111 : : 17.5 : 20;

so that it is composed of

1 atom of nitrogen, - - -	17.5
2 atoms of oxigen, - - -	20.
And its atomic weight must be -	37.5

Again, the specific gravity of nitric oxid must be

$$\frac{1111 + 972}{2} = 1041.$$

The compounds of oxigen and nitrogen afford a beautiful illustration, not only of the union of bodies in definite proportions, but also of the laws established by Gay Lussac, with respect to combination of gases in simple ratios by volume, and the space they occupy when united.

In nitrous oxid, 2 of nitrogen unite with 1 of oxigen, affording only 2 of the compound, so that the condensation is equal to the volume of the oxigen. Nitric oxid contains equal volumes, so that the oxigen in it is exactly double of that in the other, and here there is no change in the bulk.

Nitric oxid is not affected by heat, by light, nor by electricity. It does not support combustion, except in a few instances; thus, a candle or sulphur match, when put into it, is instantly extinguished. It has, however, been already said, that charcoal may be burned in it. We are not acquainted with its effects on respiration, indeed it cannot be breathed, for the moment it comes in contact with the air always existing in the mouth, it is completely changed.

The most remarkable property of nitric oxid, is its action with air, or with oxigen gas. The moment it is mixed with either, red fumes are formed, and which are nitrous acid. This experiment is easily performed. We have merely to lift a jar full of it from the water trough on which it is standing, and the fumes instantly appear. The action is owing to the gas uniting with the oxigen of the air, by which the acid fumes are generated; and that it is so, may be shewn in different ways. Into a jar half full of air, confined by water, admit bubbles of nitric oxid, so long as red fumes appear; and a gas will remain, which extinguishes a lighted candle when put into it, so that the air must have lost its oxigen. Again, into a jar

half full of nitric oxid, admit nitrogen gas, and there are no red fumes; but if oxigen be introduced, they appear. If the oxigen and oxid be pure, and mixed in proper proportions over water, the whole disappears, the product being absorbed almost the moment it is formed.

Chemists have differed widely with respect to the proportions in which oxigen and nitric oxid unite. Priestley found, that when 1 of the former and 2 of the latter were used, the absorption was almost complete, shewing that the whole had entered into union. Lavoisier states the proportions to be much less, while Ingenhouse, Humboldt, Berthollet, and others, conclude that it is greater. This discordance arises partly from the impurity of the gases, but principally from the method followed in mixing them. Thus, if the jar is large, so as to expose a great surface of water, by which the absorption is rapid, the oxigen consumed is less than it ought to be, and again, the consumption, by adding the oxigen to the oxid, differs from that produced by the addition of the oxid to the oxigen.

Dalton and Gay Lussac have, however, in their experiments, found, that though the proportions in which they unite vary, yet under similar circumstances, the consumption is the same; according to the latter, 100 of oxigen gas condense from 134 to 365 of oxid, if the experiment be performed over water, but when it is not present, they consume 204, or more probably 200. Now, in these three cases, three different compounds are formed, that with 134 being nitric acid, with 200, nitrous acid, and with 365, hyponitrous acid.

When the property of nitric oxid uniting with oxigen was discovered, it was applied to the purposes of *eudiometry*, or of ascertaining the quantity of oxigen in gases. This was first recommended by Priestley, and from the ease with which it could be done, and the quickness with which the result was obtained, it promised to be of great utility, but it is now known to be liable to so many objections, that little confidence is placed in it. Nitric oxid is frequently, however, employed as a test of the presence of oxigen, which it will detect even

though in very small quantity. It has been already mentioned, that nitric oxid does not act with nitrogen; if, however, a little oxigen be present, the red fumes appear, hence we can easily ascertain whether the nitrogen procured by the process stated, is pure, that is, if the whole of the oxigen has been removed. We have merely to admit a few bubbles of nitric oxid into a jar of it. If no fumes are produced, it is of course pure.

Nitric oxid does not act with hydrogen gas. Even when heated, or when an electric shock is passed through them, they do not explode. The mixture is, however, acted on by spongy platinum, the hydrogen uniting with the oxigen, and setting the nitrogen free.

Water after distillation, so as to free it from impurities, absorbs, according to Davy, 1-10th of its bulk of nitric oxid; 100 cubic inches of it, when freed of its air by boiling, took up 11.8. A different effect is, however, produced, when common water is employed, because the air in it decomposes the gas, and forms a little nitric acid, which is absorbed.

Nitric oxid has no action with nitrous oxid. When they are mixed over water, there are no fumes, and this want of action is probably owing to the oxigen in the latter being held by too powerful an affinity.

Nitric oxid cannot be procured by the direct combination of its ingredients; we are obliged, therefore, to have recourse to the decomposition of compounds containing them. That always employed is nitric acid, which has the same ingredients, but with the oxigen in larger proportion, so that all that is necessary is to deprive it of a part of this, by which it is reduced to nitric oxid, and for this purpose, almost any metal may be used, but that generally employed is copper. *(See Copper.)*

Oxigen and nitrogen unite in other properties, and form different compounds, all of which are acids; they will therefore be considered under the class of acids.

Nitrogen unites with hydrogen, and generates a gaseous fluid called *ammonia;* but as it is possessed of alkaline properties, it will be considered under that class.

Various attempts have been made to discover the nature

of nitrogen. Berzelius, partly from experiment, partly from reasoning founded on the atomic doctrine, has concluded that it is a compound of oxigen and an unknown base, to which he has given the name of *nitricum;* but of the existence of this we have no satisfactory proofs. Experiments have also been performed by others, in which compounds containing nitrogen have been used, as the volatile alkali ammonia, *(see Ammonia,)* and from which some have been inclined to infer that it is a compound. This conclusion must, however, be received with great caution. In the present state of the science, it must be considered a simple body.

Nitrogen, as has been already mentioned, exists in large quantity in the atmosphere. It is emitted, also, from some waters; a remarkable instance of which is at Hossick in New York, the springs in the vicinity of the town yielding it in such abundance, that a quart of it may be procured in about ten seconds, by pressing on the gravel adjoining the water, and holding an inverted jar over the spot from which it issues.

Carbon, or Charcoal.

Charcoal is in general prepared by collecting a quantity of wood into a heap of a conical form, with a base of about 10 or 12 feet, and 6 or 8 high. It is covered with turf, and then kindled; and after the flame seems to have reached the whole of it, the admission of the air is prevented as much as possible by putting on more turf. The combustion is thus allowed to go on slowly and imperfectly, by which the wood loses its watery and gaseous part, and is completely charred. As thus prepared, it is light and porous, and retains the form of the wood from which it is obtained. A much purer charcoal is now procured, by subjecting wood in large cast iron cylinders to a red heat, so as to exclude it from the action of the air. When the whole of the gaseous ingredients is disengaged, the fire is extinguished, and the charcoal allowed to cool in the cylinders, or it is removed from it, and instantly put into iron boxes, in which it is kept ex-

cluded from air till quite cold. During this process, carburetted hydrogen gas, and watery vapour, are given off, the former produced by the union of carbon and hydrogen, and the latter by the union of hydrogen and oxigen, existing in the wood. At the same time, there is disengaged a considerable quantity of impure acid, called *pyroligneous*, and which by distillation yields acetic acid. *(See Vinegar.)*

When charcoal is required for particular experiments, it ought to be procured by putting small pieces of wood into a crucible, covering them with sand, and subjecting them to a full white heat for some time, by which the whole of the gaseous matter is given off. It should then be removed from the fire, and when hot, put into bottles with sand, or, which is better, into inverted jars full of mercury, and kept there till required, so as to exclude it from air and moisture.

Charcoal, as thus prepared, is not, however, pure carbon. All vegetable bodies contain saline and earthy matter; and as it is known that these are not destroyed, or dissipated in vapour by heat, it is evident that the charcoal must retain some of them. Hence, even when well prepared, saline and earthy matter is always found in it; but the quantity is trifling, in general not exceeding 2 per cent.

Different woods afford different quantities of charcoal.

Lignum vitæ yields -	17.5 per cent.
Ebony, - - -	30.5
Brazil wood, - -	26.
Satin wood, - - -	20.7
Tulip wood, - -	20.8
Botany Bay wood, - -	28.1
Fir, - - -	18.
Boxwood, - -	20.25
Oak, - - -	17.4
Mahogany, - - -	15.75
Beech, - - -	15.

Lavoisier considered charcoal as pure carbon, with the exception of the admixture of a little saline and earthy

matter; but others have supposed that it is not so. Morveau, from his experiments, concluded that it contained oxigen, an opinion afterwards shewn by Allan and Pepys to be incorrect. Berthollet supposed also, that hydrogen existed in it as one of its ingredients, an opinion adopted by Cruickshank and others, and apparently confirmed by an experiment of Davy, who found, that on subjecting it, even though recently prepared, to the action of galvanism, an inflammable gas containing hydrogen was disengaged. Clement and Desormes, and also Allan and Pepys, have, however, shewn, that when newly formed, it does not, during its combustion, afford moisture, which it ought to do if it contained hydrogen; so that in those instances in which compounds containing hydrogen have been got from it, it may be safely inferred that they owed their formation to the presence of moisture, from which it is very difficult to keep it free. We must therefore consider charcoal as carbon pure, with the exception of the saline and earthy matter.

Charcoal prepared from wood possesses several remarkable properties. It has the power of absorbing gases, some of them in very large quantity. If a piece of it, while hot, be plunged under mercury, and after becoming cold, be introduced into a jar of gas kept also over mercury, it absorbs it, the quantity differing in different cases. This was first observed by Priestley, but it was afterwards more fully investigated by Morozzo, Rouppe, and Saussure, the last of whom has performed the greatest number of experiments on it. According to him, 1 volume of charcoal took up of

	Vol.		Vol.
Oxigen	9.2	Nitrogen	7.5
Hydrogen	1.75	Nitrous Oxid	40.

The quantities of the other gases, not yet described, were in general much greater. Thus, it took up of

Carbonic oxid	9.42	Sulphuretted hydrogen	55.
Olefiant gas	35.	Muriatic acid	85.
Carbonic acid	35.	Ammonia	90.
Sulphurous acid	65.		

The charcoal used in these experiments was got from boxwood, and was kept in mercury till cold, and then introduced into the gas, without allowing it to come in contact with air. The gases thus absorbed, may again be expelled, unchanged in their properties, by the application of heat. If, however, after having absorbed one gas, it be exposed to another, it gives off part of the former, and takes up some of the latter, provided there is no chemical attraction between them, and the quantity retained is in the ratio of what it would absorb of each separately. If it has absorbed one, and be exposed to another, between which and that previously imbibed there is an affinity, it is stated by Rouppe that they unite. Thus he found, that after having absorbed hydrogen, and then kept in oxigen, the latter was also taken up, and water was given off by the application of heat. Having imbibed hydrogen, and then exposed to nitric oxid, water and nitrogen were formed, or when kept in atmospheric air, it is said to have deprived it entirely of its oxigen.

From the large quantity of some of the gases taken up, there must be a strong attraction between them and the charcoal; it must not, however, be supposed that it is chemical; it depends solely on the mechanical structure, for it loses entirely its absorbing power by being reduced to powder.

Newly made charcoal absorbs moisture with avidity. Allen and Pepys found, that when exposed to air for twenty-four hours, it increased considerably in weight, but the quantity varied in different cases. Lignum vitæ charc al increased about 9 per cent. while that from fir increased 13, from beech 16, and from mahogany 18. When the charcoal was kept in mercury heated to 214, water was expelled.

Charcoal is not liable to putrefy; hence it is customary to char the end of stakes that are to be driven into the ground, by which they are not only preserved, but penetrate the earth more easily. Charcoal also possesses the

remarkable property of depriving bodies of their colour, taste, and smell. When water has become putrid, from having been kept long in wooden vessels, it is deprived of its putridity, by filtering it through charcoal in powder, a method often resorted to in long voyages. For this purpose, a quantity of it is put into the casks, and, after being shaken, the powder is allowed to fall to the bottom, and the water may be drawn off clear. A better mode, however, and the one now usually practised, is to char the inside of the cask, by which putridity is entirely prevented. Malt liquor, by being mixed with charcoal, is also deprived of its colour, and the disagreeable flavour it usually has when recently prepared. Putrid animal matter likewise loses in a great measure its unpleasant taste and odour, by rubbing it with charcoal powder, and allowing it to remain on it for some time. For the success of these different processes, the charcoal ought to be newly made; or if it has been kept for some time, it must be exposed to a red heat, and excluded from the air till cold. For some of them, particularly for removing colour, animal charcoal is preferred. That sold under the name of *ivory blacking*, procured by exposing ivory or bone to heat, is generally employed.

This property is valuable to chemists, as it enables them to decolorise fluids, and thus to observe the colour of precipitates formed in them. All that is necessary, is to shake the fluid and charcoal together, for some time, and then throw them on a filter. If the fluid should not pass through colourless, it must be returned, and the filtration repeated, till the colour is destroyed, or till there does not seem to be any farther action.

The atomic weight of carbon is 7.5.

Charcoal is a very bad conductor of heat, a small piece of it, though one end is in a state of combustion, may be held in the hand with impunity. When heated in close vessels, a little gaseous matter is given off, which is a mixture of gases containing carbon, in union with oxigen, and hydrogen, but the emission of them soon ceases.

These, it has been already said, are foreign, and are derived from the decomposition of moisture. After this, the carbon is left pure, with the exception of the saline matter, and does not undergo any farther change, even though exposed to the most intense heat which has yet been excited. Though carbon cannot be fused by heat, yet experiments have been performed, from which it appears, that it has been actually converted into vapour; but as this was effected by galvanism, they will be described under that subject. Carbon, also, when it enters into union with other bodies, assumes the vaporific state, and some of its gaseous compounds, during decomposition, deposit it almost in a crystalline form. Thus, in the preparation of coal gas, which contains carbon as one of its ingredients, there is often found a sort of crystalline matter in the retorts, and which is pure carbon: and the same is the case when coal gas is decomposed by metals, as in the patent process of making steel; by passing the gas over iron, a beautiful crystalline matter is frequently observed in the tube, and which has also been found to be pure carbon, so that it must have been set free from the gas, in a state of vapour, (An. of Phil. July 1826.)

When charcoal is heated in air, it burns, and, if well prepared, without flame, but as usually procured, it at first gives a blue flame, which, however, soon ceases. After the combustion, there remains a small quantity of white ashes, consisting of saline and earthy matter.

Charcoal burns with great brilliancy in oxigen gas, emitting beautiful sparks. This experiment may be performed, by putting into a copper cup a few pieces of charcoal previously kindled, and having placed it on a bent wire suspended from a plate of sheet iron, immersing it into a vase of the gas. If the charcoal can be got with bark on it, the effect is more brilliant. The combustion of carbon by oxigen is also well illustrated by driving a stream of the gas against the end of a piece of charcoal, making it at first pass through the flame of a candle to set the charcoal on fire.

In all of these experiments the properties of the air and oxigen are destroyed, a taper put into the residual gas being instantly extinguished. This case of combustion differs, however, from those already mentioned. These cause a diminution of the air, whereas in this, provided the substances are pure, there is no change in bulk; and that it is so, is shewn by having recourse to the bladdered apparatus, (p. 176.) If the jar be filled with oxigen, and placed over a cup with burning charcoal, the combustion continues, but there is no rise of the water, proving that there is no diminution; and this is owing to the generation of a gaseous compound, occupying the same volume as the oxigen consumed in its formation, and which is called *carbonic acid.*

As a great deal of reasoning with respect to the composition of bodies depends on an accurate knowledge of the constitution of this body, it has engaged the attention of many distinguished chemists. Lavoisier was the first who pointed out its composition, and endeavoured to ascertain the proportion of its component parts. In one experiment in which charcoal was burned in oxigen, using every precaution so as to have them pure, he inferred, from the quantities consumed, and the weight of the product, that they had united in the ratio of 71.11 of the latter, to 28.89 of the former. Clement and Desormes afterwards repeated the experiment of Lavoisier, varying a little the manipulation, by inflaming the carbon in oxigen by means of a lens. They fixed the proportions at 71.4 to 28.6, a conclusion confirmed by Tennant, and by Allen and Pepys.

As carbonic acid is of the same volume as the oxigen employed in its formation, this affords us another, and perhaps more satisfactory method of ascertaining the proportion of its ingredients, because the former must be heavier than the latter, by the weight of the carbon with which the latter has united so as to form it; we have therefore merely to deduct the specific gravity of oxigen from that of the acid, and the residue is the

weight of the carbon. The specific gravity of the acid is 1527.7, of the oxigen 1111.1, and

$$1527.7 - 1111.1 = 416.6$$

so that they are in the ratio of 1111.1 to 416.6, and as

$$1527.7 : 1111.1 :: 100 : 72.75$$

so that by this way the proportions are

Carbon 27.25.
Oxigen 72.75.

Again, as $27.25 : 72.75 :: 7.5 : 20$

so that it is composed of

1 atom of carbon,	7.5
2 atoms of oxigen,	20.
and its atomic weight is	27.5

As 416.6 is the weight of carbon in 1527.7 of carbonic acid, supposing the carbon to be gaseous, 416.6 must represent its specific gravity, so that, in another point of view, we may consider the acid to consist of

	Vol.		Vol.
Carbon gas,	1	} condensed into	1.
Oxigen gas,	1	}	

The properties of carbonic acid will be given under the class of acids.

Carbon and oxigen unite in other proportions, and form a gaseous compound, which, as it has not acid properties, is called

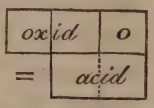
Carbonic Oxid.

It was first discovered by Priestley, though he did not ascertain its nature. Cruickshank was the first who pointed out its composition and qualities.

It cannot be obtained by the direct combination of its ingredients, but it may be procured by the decomposition of carbonic acid; and all that is necessary is to subject it to the action of a substance which will deprive it of part of its oxigen, as iron or charcoal. For this purpose, having stuffed the tube *(see Cut, p.* 138,) with charcoal, and brought it to a red heat, some pieces of chalk are put into the retort, and muriatic acid pour-

ed on them, by which carbonic acid is disengaged, and passing through the tube is decomposed by the charcoal, which deprives it of an atom of oxigen to form carbonic oxid, while by losing oxigen it also becomes oxid, which passes off in the state of gas, and may be collected in the jar, but as some of the acid escapes decomposition, it is necessary to have the trough filled with lime-water, which will absorb it and leave the oxid pure.

Carbonic oxid is a transparent colourless gas, of specific gravity, according to Thomson 972, 100 inches weighing 29.65 grains. Its atomic weight is 17.5. It is unfit for the support of respiration. It is sparingly absorbed by water. When heated in contact with air, it burns with a blue lambent flame, and during its combustion forms carbonic acid. When mixed with oxigen and heated, it is exploded, and also forms carbonic acid, the proper proportions being two of oxid to one of oxigen, and they may be fired either by electricity or by heat:



The product is two volumes of carbonic acid. From this experiment we are enabled to fix the proportions of its ingredients. As carbonic acid contains its own volume of oxigen, the two formed in this experiment must contain two, but one has been added to cause the explosion, the other must have been derived from the oxid, so that two contain only one, in other words, it has half its volume of oxigen. But again, carbonic acid contains its own volume of carbon gas, so that the two formed must contain two, and which have been got from the oxid, so that each volume contains one of carbon gas, and half of oxigen gas, condensed into one; it has, therefore, keeping the carbon the same in both, just half the quantity of oxigen that exists in the acid. The proportions of the acid have been stated to be 1111 to 416, so that in the oxid they are 555 to 416.

And as 555 : 416 : : 57.14 : 42.86,

so that the component parts are,

Carbon	42.86
Oxigen	57.14

Again, as 42.86 : 57.14 : : 7.5 : 10,
so that it is composed of

1 atom of carbon 7.5
1 atom of oxigen 10.

and its atomic weight is 17.5

As the explosion by electricity shews that it is composed of one volume of carbon gas, and half a volume of oxigen, together making one, its specific gravity must be half that of oxigen added to that of carbon gas ;

$$555.5 + 416.6 = 972.2.$$

Carbonic oxid is decomposed by hydrogen, when passed through an incandescent tube, water and carbon being formed.

Carbonic oxid explodes also with nitrous oxid, by means of electricity. Using 2 volumes of each, the products are 2 volumes of carbonic acid, and 2 volumes of nitrogen. Now, as nitrous oxid is composed of 2 volumes of nitrogen, and 1 of oxigen, condensed into 2, this shews that carbonic oxid contains also half its bulk of oxigen, one being derived from each, to form the two of carbonic acid.

If we consider carbonic oxid as composed of an atom of each of its ingredients, and that it contains 1 volume of oxigen, and 2 of carbon vapour, the atom of the former being represented by 1 volume, that of the latter must be represented by 2 volumes ; and it is of importance to keep this in view, in enabling us to fix the proportions of the ingredients, and the atomic weights of its other compounds.

Carbonic oxid is not put to any use.

Carbon unites with hydrogen in different proportions, and forms compounds possessed of different properties. With two of these we have been long acquainted, the others have been but lately discovered, and some of them, though there is every reason to believe their existence, have not yet been procured in their separate state. The two first mentioned are carburetted hydrogen and olefiant gas.

It was at one time supposed, that the compounds of carbon and hydrogen contained oxigen, and that all of these ingredients entered into union, in different proportions, and formed substances possessed of properties essentially different. The experiments of Dalton, Henry, Davy, and others, have however shewn, not only that oxigen does not exist in them, but that, as in other compounds, the proportions of hydrogen and carbon are fixed; and that this is the case, will appear evident from the detail of their properties.

Hydroguret of Carbon, or Olefiant Gas.

This gas was discovered by the associated Dutch chemists in 1798; and it has since been examined more accurately, and its true nature pointed out, by Dalton, Saussure, and Thomson.

It cannot be procured by the direct combination of its ingredients; we are therefore under the necessity of having recourse to decomposition. The substances usually employed in its preparation, are oil of vitriol, and spirit of wine, which are merely placed in a retort, and heated by means of a lamp, by which a gaseous fluid is given off, and which is olefiant gas, with a slight admixture of carbonic acid, but from which it is freed by collecting it in a lime water trough. *(See Alcohol.)*

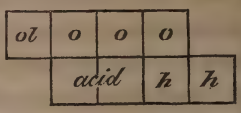
Olefiant gas is transparent and colourless; hence invisible. Its specific gravity has been differently stated by authors. According to the Dutch chemists, who discovered it, it is 909, while Henry makes it 967, and Saussure 985. Dr Thomson, however, considers it to be 972, 100 inches weighing 29.65 grains. Its atomic weight is 8.75.

When electric sparks are passed through it, it is decomposed; carbon is deposited, and a gaseous fluid is formed, occupying exactly twice the volume of the olefiant gas, and which is pure hydrogen; from which it is evident that each volume contains two of hydrogen, compressed into one.

When heated in contact with air, it burns with a bright

white flame, and by which it is easily distinguished from all other gases. The products are carbonic acid and water.

When mixed with oxigen and heated, or by the transmission of electricity, it explodes, the proper proportions being 1 of gas to 3 of oxigen; and by this experiment we are enabled to fix the proportion of its ingredients: 3 of oxigen, and 1 of olefiant, form, by explosion, 2 volumes of carbonic acid; the only other product is water. Now, as carbonic acid contains its own bulk of oxigen, 2 of this gas must have been consumed in the formation of the 2 of acid, the remaining 1 must therefore have united with the hydrogen to form water; but 1 of oxigen unites with 2 of hydrogen, so that in 1 of olefiant there are two of hydrogen. If, then, we deduct twice the specific gravity of hydrogen from that of olefiant, the remainder will be the weight of the carbon.



$$972.2 - 138.8 = 833.4, \text{ and}$$
$$138.8 : 833.4 :: 14.35 : 85.65,$$
$$\text{and as } 14.35 : 86.65 :: 1.25 : 7.4,$$

sufficient to prove that it is a compound of

1 atom of carbon	7.5
1 atom of hydrogen	1.25
And hence its atomic weight,	8.75

Carbonic acid, it has been already proved, contains its own volume of carbon vapour, so that if 1 of olefiant, by explosion, yields 2 of acid, it must contain 2 of carbon condensed into 1.

Olefiant gas, when heated with nitric oxid, is exploded, 1 of the former requiring 6 of the latter, and the products are, 3 of nitrogen, 2 of carbonic acid, and water. Now, as nitric oxid is composed of equal volumes of oxigen and nitrogen, united without condensation, the 6 must contain 3 of the former, 2 of which must have gone to form carbonic acid, and the remaining 1 water; so that here again the composition of olefiant gas is proved to

be 2 of the vapour of carbon, and 2 of hydrogen, compressed into 1; and here, also, as there are 2 of hydrogen, and 2 of carbon vapour, it is evident that it contains an atom of each, the atoms of each being represented by 2 volumes.

Since this is the case, its specific gravity must be,

sp. gr. of hyd. $\times$ 2 + sp. gr. carbon vapour $\times$ 2;

i. e. $416.6 \times 2 + 69.4 \times 2 = 972$.

The property from which olefiant gas has derived its name, is that of forming an oily-looking fluid with chlorine, remarked by the Dutch chemists who discovered it. *(See Chlorine.)*

Bi-Hydroguret of Carbon, or Carburetted Hydrogen.

Carburetted Hydrogen was first examined by Priestley, and afterwards by Cavendish, and it has lately been made the subject of investigation by Dalton, Thomson, and Davy.

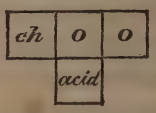
It cannot be procured by the direct combination of its ingredients, but it is easily obtained by other means, perhaps the most simple of which is, by the decomposition of water. All that is necessary, is to pass its vapour over red hot charcoal. For this purpose, having stuffed an earthenware tube with charcoal, *(Cut, p.* 138.*)* it is brought to a red heat, by passing it through a chauffer or furnace; and when this is done, the water in the retort is made to boil, by which the vapour flows through the tube, and is decomposed; the hydrogen unites with part of the carbon to form carburetted hydrogen, while the oxigen, the other ingredient, is combined with the remainder, to form carbonic acid. These come off together, and may be collected in the jar, or a gas-holder may be filled with it, by putting the mouth of the tube into it. To remove the carbonic acid, it is merely necessary to have the jars, or the gas-holder, filled with lime water, the lime of which unites with it, so that the car-

buretted hydrogen is thus got pure. It may also be got by other means, as will be afterwards noticed.

Carburetted hydrogen gas is transparent and colourless. It is, when pure, destitute of smell; but as usually prepared, it has a faint peculiar odour. It is much lighter than air; but its specific gravity has been differently stated. According to the latest experiments of Thomson, it is .555, 100 inches weighing 16.92.

When electric sparks are passed through it, carbon is deposited, and pure hydrogen is left, occupying exactly twice the volume of the carburetted hydrogen, and which shews, therefore, that, bulk for bulk, there is the same quantity of hydrogen in this as in olefiant gas.

When heated in air, it burns with a pale reddish flame, the products being water and carbonic acid. If it be mixed with oxigen, and heated, or electric sparks passed through it, it is exploded, the proper proportions being 2 of oxigen to 1 of gas; and during the explosion, 1 of carbonic acid is formed. We are thus enabled to fix the proportions of its ingredients. It has been already mentioned, that by electricity it is shewn to contain the same quantity of hydrogen as olefiant gas; but 1 volume of the latter yields 2 of carbonic acid, whereas 1 of this yields only 1, so that it must have only half the quantity of carbon, or, which is the same thing, twice as much hydrogen. Olefiant gas, it has been already shewn, is composed of atom to atom; carburetted hydrogen must therefore be a compound of



1 atom of carbon,	7.5
2 atoms of hydrogen,	2.5
and its atomic weight is	10.

And that this is its atomic composition, is evident, for as it contains 1 volume of carbon, and 2 of hydrogen, but the atom of the former is represented by 2 volumes, the hydrogen must be 4 volumes, that is, 2 atoms; and hence Thomson has proposed to call the former hydroguret, and the latter bi-hydroguret of carbon. As it contains

2 of hydrogen, and 1 of carbon vapour, condensed into 1, its specific gravity must be

$$69 \times 2 + 416.6 = 555.$$

It is remarkable, that though carburetted hydrogen is easily inflamed when heated in contact with air, yet it cannot be kindled if it be mixed with an equal bulk of it, or even if it be between that and 1-6th. From this to 1-12th it is easily exploded.

Water absorbs about 1-27th of its bulk of it.

Carburetted hydrogen is an abundant production of nature. It is emitted copiously from stagnant pools, and may be easily collected, by inverting a jar, and stirring the pool, by which a gaseous matter is given off, containing carburetted hydrogen and carbonic acid, from the latter of which it may be freed, by washing with lime water.

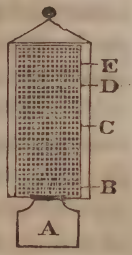
It is also emitted from coal in coal mines, through the chinks of which it issues, in some in great abundance, and as it is lighter than atmospheric air, it ascends, mixing with it as it rises. As it increases in quantity, it gradually occupies more and more of the mine, till it reaches the lights used by the miners, by which it is inflamed, and from the immense quantity of it, it explodes with tremendous violence, and produces the most dreadful consequences. The discovery of a means of preventing this evil, for many years occupied the attention of several distinguished philosophers, but without success. Attempts were made to ventilate mines thoroughly, in the hopes that, by keeping up a constant change of air, the inflammable gas might in a great measure be carried away. When this could not be done, miners used occasionally to set fire to the gas, before much of it was collected; at the same time, the person who kindled it stood in water, and the moment he thrust the candle into it, he plunged under the fluid. By these means, the dreadful consequences of the explosion were in a great measure prevented. There was still, however, cause to regret, that they occasionally occurred, perhaps from the carelessness of the workmen, or from the greater emission of

gas at one time than another. We can now, however, boast of a preventive of these fatal explosions, in the safety lamp of Davy, which has been proved, by the most ample trials, to avert completely the danger arising from using lights in coal mines, even though abounding with an explosive mixture.

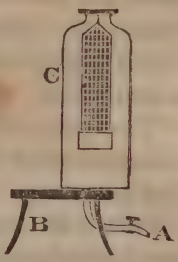
In his experiments, made with a view to ascertain how to prevent explosion in mines, Davy discovered that flame would not pass through very small tubes of glass, or metal, nor through very fine wire gauze. He therefore concluded, that to light mines, in which there is a collection of inflammable gas, it is merely necessary to have a lamp so formed, that the air requisite for the combustion should enter through minute apertures. In the first he employed, the air was allowed to pass through a piece of wire gauze, placed at the bottom, the flame, as usual, being surrounded by glass or horn. He afterwards found, however, that if a lamp, surrounded on all sides by wire gauze, be put into an inflammable mixture, the air necessary for the combustion enters through the holes of the gauze, taking along with it the inflammable gas, which is also consumed, but the flame does not communicate to the explosive mixture without. The lamp was therefore constructed in this way. After being kindled, it was exposed to a mixture of air and carburetted hydrogen in a mine, which, passing through the gauze, was kindled by the flame of the lamp, and burned; and as there was a constant renewal of it, not only light was thus afforded, but the destructive element, the carburetted hydrogen, was itself consumed. When the gas is mixed with about 12 of air, the flame of the lamp continues within that of the gas; but when there is only about 7 of air, the flame of the wick is extinguished, but that of the gas continues, and thus also affords light, which, though feeble, is sufficient for some purposes.

Though wire gauze is thus a preventive to the passage of flame, yet, should the wire become red hot, provided it be of sufficient thickness, it may set fire to the gas. It

is necessary, therefore, to have it of the requisite size; about the 1-40th, or 1-60th of an inch, is found to be the best; and to prevent any danger arising from the overheating of the wire, as that above the flame of the wick is the only part likely to become so, the gauze has a double top; so that, should that immediately over the flame become red hot, it will explode the gas above it, or that between the inner and outer top. A is the lamp, with its flame, B. C is the cylinder of gauze, terminating with a top at D; and over this is another cylinder, E, coming down over C, about an inch. There must also be at least a certain number of holes in the square inch; from 500 to 600 have been found to answer best.



That there is no danger in putting this lamp into an explosive mixture of air and carburetted hydrogen, may be easily shewn on a small scale. Having filled a gasholder with the gas, the flexible tube, A, coming from it, must be passed through a hole in a stool, B, and over this is to be placed a glass, C, open above and below, in which the lamp is suspended, the upper aperture being covered with a piece of paper or cloth. On opening the cock, so as to allow the gas to flow in very gradually, it displaces a part of the atmospheric air, so that there is an explosive mixture in the jar, which is constantly passing into the lamp through the holes in the gauze, by which the combustion is kept up, and, as the mixture is consumed, the jar being open below, there is a constant admission of air, to be mixed with the gas coming from the pipe. In this experiment, when the air is in considerable quantity, the flame of the lamp is seen within that of the gas with which the cylinder of gauze is filled; but when the air diminishes, the former is extinguished, but the latter continues as long as the proper proportions can be kept up, affording a beautiful flame within the gauze, and which



does not pass through to the explosive mixture by which the lamp is surrounded.

That wire gauze is a preventive to the passage of flame, may be shewn still more easily. If we set fire to a jet of gas, and hold a piece of gauze over it, the flame is seen only below, provided we do not keep the same part always over the pipe, for, in this case, the wire becomes red hot, and kindles the gas above. Or if a jet of gas be allowed to pass through the gauze, and be kindled above, the flame does not communicate to that below.

The effect of wire gauze in preventing the passage of flame, is supposed to be owing to its cooling power. Sir H. Davy considers flame as gaseous matter, kept in a state of incandescence by the high temperature generated during the combustion, and which he conceives to be above that of the incandescence of solids, consequently when any cool object is brought near it, the temperature is so much reduced, that it is no longer luminous. Hence, when the gaseous matter passes through the meshes of gauze, it is instantly cooled by the wire, and even though this is brought to a red heat, it is not sufficient to make it luminous.

The other compounds of carbon and hydrogen will be described when detailing the method of manufacturing coal gas.

Carbon and nitrogen may be made to enter into union, and form a gaseous fluid discovered by Gay Lussac, and to which he gave the name of *Cyanogen*, from the blue colour of some of its compounds. As it is a compound acidifiable body, it will be described under that class.

Carbon, or, more properly speaking, charcoal, is used abundantly as fuel, particularly in those countries where coal cannot be procured. It serves well for many purposes in which smoke and flame would prove injurious: and hence its use in chauffers and furnaces. When employed in stoves in apartments, great care ought to be taken to have a free ventilation, for though there is no smoke, yet it vitiates the air materially, the carbonic acid generated being very noxious to the animal sys-

tem, and if in large quantity, proving fatal when breathed. That the qualities of the air are changed may be shown, by holding a jar, open at both ends, over a chauffer of charcoal for a few minutes; the product of the combustion rises and fills it, and if, after removing it, and placing a plate at the bottom, a lighted taper is introduced at the upper aperture, it is instantly extinguished.

Charcoal is used in the manufacture of gunpowder, and great care is now taken in the preparation of it. For this purpose, it is always procured by subjecting wood to a red heat, in large cast iron cylinders. It is used also for procuring metals in the reduction of ores. It is used instead of pencils, for taking sketches, any inaccuracy being easily rubbed out, and for this purpose it ought to be prepared from willow, which affords it of uniform softness. When employed as black paint, it should be made from ivory, as this seems to give the most intense and durable black.

The substance sold under the name of *lamp black*, is merely the soot collected during the burning of the refuse of pitch, or tarry matter. A very fine kind of charcoal may also be procured, by holding a plate in the flame of a lamp, by which it is covered with soot, which may be removed, and the plate again held in the same situation, so that, by repeating the process, a quantity of it may be collected. When the charcoal is required very pure, as for some of the finer paints, that prepared from ivory, or by the process last mentioned, should be washed with muriatic acid, or weak aquafortis, by which the whole of the impurities are removed. Charcoal, prepared in this way, is employed for affording China ink. For this purpose, 6 parts of isinglass are dissolved by boiling in 12 of water; 1 of Spanish liquorice is dissolved in 2 of water, and mixed with the former, with which one of ivory blacking is to be intimately incorporated, and the whole evaporated to the proper consistence.

From the slowness with which it conducts caloric, it is used for lining the insides of furnaces, that the heat may be retained as much as possible. For this purpose

it is mixed with sand and clay, with which the furnace is lined, the lining being protected from the action of the fire, by a coating of clay. With the same view, vessels for holding warm fluids are sometimes double, the interstice being filled with powdered charcoal.

It has been already mentioned, that charcoal is not pure carbon; it exists, however, in its pure state, in diamonds. Newton, who had previously shewn, that inflammables have a powerful effect in refracting light, concluded that diamond contained an inflammable ingredient, the correctness of which was proved in 1694, and which was done by exposing it to the heat of the solar rays, concentrated by Tschernausen's powerful lens. The inflammable nature of diamond was afterwards proved by the experiments of Lavoisier, Tennant, and others, by whom it was found that the heat of a furnace was sufficient for its consumption. Lavoisier first shewed, that the air in which it was burned contained carbonic acid, a fact which, though at first sight considered improbable, was afterwards proved by the experiments of Allen and Pepys, and of Davy, who found, not only that carbonic acid was formed, but also that its weight equalled exactly that of the diamond consumed, and of the oxigen abstracted from the air. Carbon exists also very nearly pure, in plumbago, or black lead, which has been found besides carbon, to contain a minute quantity of iron. It exists also in great abundance in the animal kingdom and from which it is often derived.

Phosphorus.

Phosphorus was discovered in 1669, by Brandt, a German chemist, when making experiments on urine. Kunkel afterwards procured it from the same fluid in 1674, but the method of obtaining it was not made public till the French government purchased the secret and revealed it.

The process followed by these chemists consisted in evaporating urine to dryness, and subjecting the residue to a red heat. Margraaf afterwards improved it by

mixing charcoal with the urinary residue, by which the phosphorus was more easily obtained; still, however, it was tedious and offensive. Scheele shortly afterwards pointed out a mode of procuring it from bones, and which, with a slight modification, is still practised. *(See Phosphate of Lime.)*

Phosphorus is generally in the form of small cylinders. When recently prepared, it is transparent and colourless, but it is generally of a pale brownish colour, and semi-transparent. When cold it is brittle, but at a medium temperature is easily cut like wax. Its specific gravity is about 1770; its atomic weight 15.

By the application of heat it is fused, the fusing point, according to Pelletier, being 99, but according to Thomson 108. When heated in close vessels, or rather in those from which air is excluded, it evaporates at 219, but it does not boil till it reaches 554. When fused, and allowed to cool gradually, it puts on a crystalline appearance. For the success of this experiment it must be melted under water, and then allowed to cool very slowly, and when the upper part is congealed, a hole is made in it, and the unconsolidated matter poured out. The inside will then present a beautiful congeries of small but well formed crystals.

Light acts on phosphorus. When exposed to it, it acquires a white crust on its surface, hence the necessity, when we wish to have it transparent, to keep it in dark glass or earthen bottles. The change effected is owing to the decomposition of the water, in which it is always kept, the hydrogen uniting with a part of it to form a gas, the properties of which will be immediately described, the oxigen combining with another part to form an oxid which encrusts it, and thus destroys the transparency. The water also in which it has been kept becomes luminous, from which it appears that phosphorus is sparingly soluble in it.

When phosphorus is exposed to the atmosphere, it emits a peculiar odour, and if in the dark, it is luminous, as may be shown by placing a piece of it in a jar of air,

or, which is perhaps still more satisfactory, by rubbing a sheet of paper with it, and keeping it in the dark, by which the traces become visible. In these cases the luminousness is owing to a slow combustion, and consequent union of the inflammable with the oxigen of the air; and that it is so, is shewn by putting a cylinder of it fixed to a cork, into a jar of air, inverted over water. It is luminous, and in the course of a few hours the water rises, occupying about 1-5th of the jar, at which time the luminousness ceases. That it is the oxigen that is removed, is proved by introducing into the residual gas a lighted taper, which is instantly extinguished.

It is very remarkable, that though phosphorus is so easily acted on by air, it does not even appear luminous in oxigen gas at a natural temperature; and that it does not, is shewn by introducing it into a jar similar to that used in the last experiment, but full of oxigen gas; indeed, it is not only not luminous in the dark, but there is no diminution of the gas itself, shewing that no action is going on.

The ease with which phosphorus is acted on by air, is supposed to be owing to the nitrogen dissolving it, and forming an elastic compound, which gives off the phosphorus to the oxigen; an opinion which seems strengthened by the fact, that if, after a piece of phosphorus has been kept in nitrogen, and during which there is no emission of artificial light, a little oxigen gas be introduced, the luminousness instantly appears.

When phosphorus is heated to about 148 in air, it is set on fire and burns with a bright white flame; and if the experiment be performed in a limited quantity of air, white flakes may be collected. For this purpose, set fire to a piece of phosphorus in a copper dish, and instantly whelm a bell glass over it; white fumes are emitted, and are condensed on the sides of the jar. If more phosphorus be used than there is air to serve for the complete combustion, a reddish matter is left on the dish, and which it has been supposed is an oxid.

When phosphorus is heated in oxigen gas, it is easily

inflamed, and burns with astonishing splendour. The experiment may be performed, as already described, (p. 173.) If the room be darkened, the effect is very brilliant.

By the union of phosphorus with oxigen, different compounds are formed. It has been already mentioned, that when kept in water, it is encrusted with a white matter, supposed to be an oxid, and the reddish substance left in the dish during its combustion in air, is imagined to be of a similar nature. The proportions of the ingredients of these compounds have not been ascertained, nor have their properties been investigated. The other compounds, and with which we are better acquainted, are possessed of acid properties, and will be considered under that class.

Phosphorus unites with different proportions of hydrogen, and forms very peculiar compounds. Hydrogen at a natural temperature slowly dissolves it, as is evident from its being luminous when kept in it in the dark. If the temperature be raised to about 400, they unite and form a gaseous fluid, long known by the name of phosphuretted hydrogen.

Hydroguret of Phosphorus, or Phosphuretted Hydrogen.

This gas was discovered by Gingembre in 1783, and afterwards by Kirwan, who was unacquainted with the previous experiments of the other. It has since been examined by Raymond, Dalton, and Thomson, the last of whom has proposed to call it *hydroguret of phosphorus*.

It is never prepared for experiment by the direct union of its ingredients. It is in general obtained by the decomposition of water by phosphorus and lime, or potassa. For this purpose, having filled the body of a small tubulated retort with a thin paste of lime and water, introduce a few chips of phosphorus, and having plunged the neck of the vessel so far as the tubulature into the water trough, so as to expel the air, introduce

the stopper, and carry on the decomposition in the usual way by the application of heat. In a short time bubbles of gas come over, and may be collected in jars, the water undergoing decomposition, giving its oxigen to part of the phosphorus to form an acid, which enters into union with the lime, and its hydrogen to the remainder, to generate the gas which escapes.

Phosphuretted hydrogen is transparent and colourless, having a disagreeable odour and bitter taste; its specific gravity, according to Thomson, is 902, 100 inches weighing 27.5 gr.

When exposed to light, particularly over water, it is decomposed, part of the phosphorus is deposited, and a gas is left, still occupying the same volume as before. It is also decomposed by electricity, by which the whole of its phosphorus is separated, and hydrogen, of the same volume as the gas itself, remains. This experiment not only shews that phosphuretted hydrogen contains its own volume of hydrogen, but points out an easy method of ascertaining the proportions of its component parts;—we have merely to deduct the specific gravity of hydrogen from that of the gas, and the remainder is the quantity of phosphorus.

Sp. gr. of ph. hyd. - -	902.7
hyd. - -	69.4
	833.3

The hydrogen is to the phosphorus as 69.4 to 833.3, or as 1 to 12, and as

1 : 12 :: 1.25 : 15

So that phosphuretted hydrogen is a compound of

1 atom phosphorus, - -	15.
1 atom hydrogen, - -	1.25
and its atomic weight is - -	16.25

Considering the phosphorus in this gas to be itself in the gaseous form, then its specific gravity is .833, two volumes of the vapour being equivalent to an atom; and keeping this in view, we can easily fix the proportions of the ingredients of its other compounds.

The action between phosphuretted hydrogen and air is very remarkable. The moment it comes in contact with it, as when a bubble from the retort is allowed to escape through the water of the trough, it takes fire, and if the air be undisturbed, a beautiful white wreath ascends, which is composed of an immense number of small rings, each revolving vertically round its own axis. It is the phosphoric acid, formed by the combustion of the phosphorus, wafted up with the watery vapour, generated by the union of the hydrogen and oxigen.

If the gas be received into oxigen, the inflammation is more brilliant; but the experiment is attended with danger, unless very little is introduced at a time. When 2 volumes of the gas are mixed with 1 of oxigen, they both disappear, water is formed, and phosphorus deposited; if, however, 3 of the latter be employed, phosphoric acid is generated, 1 of oxigen uniting with the 2 of hydrogen to form water, the remaining 2 with the phosphorus to generate the acid. Phosphuretted hydrogen and nitrous oxid detonate by means of electricity; when 1 of the former and 3 of the latter are used, 3 of azote remain, the whole of the hydrogen and phosphorus uniting with the $1\frac{1}{2}$ volumes of oxigen in the oxid, and setting the azote free. The same happens with nitric oxid; using the same proportions, only $1\frac{1}{2}$ of azote are produced.

Phosphuretted hydrogen is not put to any use.

It has been already mentioned, that by exposing phosphuretted hydrogen over water to light, phosphorus is deposited, and a gas is formed, having the same volume as the other, but of course, with less phosphorus. It is called by Thomson

Subphosphuretted Hydrogen.

It retains the odour of phosphuretted hydrogen, but does not inflame when mixed with air,—on being heated with it, or with oxigen, it burns, requiring $1\frac{1}{4}$ volume

of the latter for complete combustion. As this gas contains all the hydrogen originally in the phosphuretted hydrogen, it must contain its own volume of it, so that during the explosion this must have united with half a volume of oxigen to form water, the remaining 3-4ths of a volume must have combined with the phosphorus. In phosphuretted hydrogen the phosphorus requires 1 volume, whereas in this gas it takes only $\frac{3}{4}$, so that there must be a fourth less of phosphorus, the hydrogen being the same in both. To get quit therefore of the fractions of an atom, it must be supposed a compound of 4 atoms of hydrogen, and 3 of phosphorus.

There is still another compound of phosphorus and hydrogen, the *hydrophosphoric gas* of Davy, but called by Thomson

Bi-Hydroguret of Phosphorus.

This gas may be prepared by heating crystallized phosphorous acid (a compound of phosphorous acid and water,) in a retort, excluding the air, by which the water contained in the acid is decomposed, giving hydrogen to part of the phosphorus to form the gas, and oxigen to the remainder to generate phosphoric acid.

It is transparent and colourless, having an odour somewhat the same as that of phosphuretted hydrogen. Its specific gravity is 972.1. It does not inflame when brought in contact with air, or with oxigen, unless the temperature is elevated to 300. It requires for complete combustion 2 volumes of oxigen, 1 of which unites with the phosphorus, the other with the hydrogen. Since this is the case, it must contain twice as much hydrogen as phosphuretted hydrogen does, and if so, it has two volumes condensed into one. It is composed therefore of

1 atom of phosphorus, -	15.
2 atoms of hydrogen, -	2.5
and its atomic weight is - - -	17.5

Its specific gravity, it has been already mentioned, is 9721. This must be made up of

twice sp. gr. of hyd. - - -	138.8
once do. ph. - -	833.3
	972.1

If the preceding statement be correct, the following is the composition of the compounds of phosphorus and hydrogen in atoms:

	Phosph.	Hyd.
Phosphuretted hydrogen, - -	1	1
Bihydroguret of phosphorus, - -	1	2
Subphosph. hydrogen, - - -	4	3

In the last of these the law of multiples does not hold true, which has led some to suppose that it is not a distinct compound of hydrogen and phosphorus, but a mixture of some of the others, in certain proportions.

Phosphorus is not put to any particular use. From the ease with which it unites with oxigen, it is sometimes employed in eudiometry, for which purpose it answers extremely well, as the experiment is easily conducted. All that is necessary, is to introduce a stick of it into a graduated jar, say with air, standing over water, and leave it there for some hours, or till it ceases to be luminous in the dark, by which the oxigen is consumed, and the water rises to supply its place; of course the height at which it stands, indicates the quantity of oxigen removed, attending to the usual precautions with respect to temperature and pressure.

BORON.

The salt called borax, has been long known to contain a peculiar acid in union with soda, but it was not till lately that we became acquainted with its composition, though, from analogy, it was considered a compound of a base, and oxigen. In 1807, Davy subjected it to the galvanic influence, and found that a black powder was collected around the negative wire, but he did not then prosecute his inquiries farther. In 1808, Gay Lussac and Thenard succeeded in decomposing it, by exposing it to the action of potassium; and Davy, nearly

about the same time, effected its decomposition by a similar process, and procured a sufficient quantity of the base, to enable him to ascertain a few of its properties. He gave it the name of *Boron.*

Boron is of a dark brown colour, without taste and smell. When heated in close vessels, it does not suffer any change, in this respect resembling charcoal, the most intense heat not being able to fuse it. It is a non-conductor of electricity. When heated in air to about 600, it burns with considerable splendour. In oxigen gas the combustion is more brilliant, but as the oxigen is consumed, a white crust is formed, which puts a stop to the action, so that if it is required to consume the whole of it, the product must be repeatedly washed, and the residue heated in the gas. The substance formed possesses all the properties of boracic acid, which will be described along with the other acids.

The atomic weight of boron is, according to Thomson, 10.

The actions of boron with the other substances already mentioned, have not yet been ascertained.

ARSENIC.

The name *arsenic*, was applied by the ancients to a substance of a reddish colour, used by them as a paint, but its composition was not then known; and with another now commonly sold under the same name, we have also been long acquainted. These have been discovered to contain a peculiar base, in the one, in union with sulphur, in the other, with oxigen, and to which the name of *arsenic* has been given. Its properties have been examined by Scheele, Bucholz, Proust, and Berzelius.

Arsenic is of a bluish grey colour, with considerable lustre. It has a foliated texture, and is very brittle, being easily reduced to powder. It is inodorous at common temperatures, but when heated, it emits the smell of garlic. Its specific gravity 576.3. Its atomic weight 47.5. When heated to about 356, it passes off in

vapour, and without becoming liquid, the vapour having the peculiar garlic odour, and as it cools, forming slender tetrahedral crystals.

When exposed to the air, it very soon becomes black, and falls into powder, but it does not suffer much change in water, and hence when it is wished to preserve the lustre, it is generally kept in that fluid. When heated in air, it burns, owing to its uniting with oxigen.

Arsenic combines with two proportions of oxigen, and forms compounds, which were at one time considered oxids, but are now allowed to be acids. *(See Acids.)*

Arsenic unites with hydrogen, and forms a gaseous compound discovered by Scheele, and since examined by Tromsdorff, Proust, Stromeyer, and Gay Lussac and Thenard. More lately, its properties were investigated by Gehlin, who fell a victim to it in 1815.

Different methods have been recommended for preparing it. That followed by Tromsdorff, consists in putting 4 parts of the metal zinc, and 1 of arsenic, into about 4 of oil of vitriol, diluted with rather more than its own bulk of water, by which the oxigen unites with the zinc to form an oxid, which will combine with the sulphuric acid, while the hydrogen enters into union with the arsenic, and forms a gaseous compound, called

Arsenuretted Hydrogen.

Arsenuretted hydrogen gas, is transparent and colourless, of specific gravity 2708, according to Thomson. It has the peculiar garlic odour of arsenic in vapour. It does not support combustion, and when breathed, even though largely diluted with air, proves speedily fatal, and hence the necessity of very great caution when experimenting with it.

When heated in contact with air, it burns with a blue flame. If the combustion go on slowly, water is formed, and the arsenic is deposited on the sides of the jar; but if it be rapid, as when exploded with oxigen, there is no deposition, the arsenic being converted into an acid.

When chlorine is mixed with arsenuretted hydrogen, there is a decomposition. Muriatic acid is formed, and arsenic is deposited.

Various attempts have been made to ascertain the proportion of the ingredients of this compound, but without success. In one experiment, Gay Lussac found, that when 100 measures were decomposed by a metal, which would unite with the arsenic, 140 of hydrogen were liberated; from which it would appear, that it contains 3 of hydrogen, condensed into 2.

It is supposed that there is another compound of arsenic and hydrogen. When water is decomposed by galvanism, using wires of arsenic, the hydrogen evolved is in smaller quantity than when platinum wires are used; at the same time a brownish substance is formed, which, when heated, gives off arsenic and hydrogen, but its properties have not been ascertained.

Arsenic is occasionally, though rarely, found in its native state, principally in union with some of the metals. It is, however, most frequently in combination with sulphur, and from which it is generally obtained, first by converting the arsenic into a compound with oxigen, and afterwards decomposing this by charcoal. *(See Arsenious Acid.)* It is not put to any particular use.

SULPHUR.

Sulphur, or brimstone, as it is generally called, is procured in the form of cylinders, and in fine powder, the latter of which is the purer, being obtained from the former by sublimation. It has neither taste nor smell, but when rubbed it has a faint peculiar odour. It is of a yellowish colour; but when procured by precipitation it is white, probably owing to its containing water. Its specific gravity is 1990; its atom 20.

When the sulphur in cylinders is slightly heated, as when held for some time in the hand, it crackles, and soon falls to pieces. When the temperature is raised to about

220, it fuses, and acquires a reddish colour; but it is remarkable, that if the heat be continued, instead of remaining fluid, it becomes viscid, so much so, as to adhere to the sides of the vessel; and the viscidity continues till the temperature arrives at about 552, at which it passes off in vapour. This was at one time supposed to be owing to oxidation; but that it is not so, is evident from its undergoing the change as often as we choose. Besides, as the temperature falls, it becomes quite limpid just before it is congealed. When sulphur is fused, and allowed to cool very gradually, it crystallizes. When heated in close vessels to about 550, it rises in vapour, which condenses in the cool part of the apparatus, in fine powder, forming *sublimed sulphur*, or *flowers of sulphur*.

Sulphur is a non-conductor of electricity.

When heated in air to about 300, it burns with a pale blue flame, and fumes are given off, which are extremely offensive to the nostrils and lungs. When it is exposed to a higher temperature, as when thrown on a red hot plate, the combustion is more vivid, and the flame is white, with admixture of red. In this instance, also, it is dissipated in fumes, which are not so offensive as the former; but when condensed, are much more corrosive. When burned in oxigen gas, the combustion is very lively, the flame being white, with a slight tinge of blue. This experiment is easily performed, by soaking some lamp cotton in melted sulphur, and allowing it to congeal; the match thus formed is placed in a spiral of wire, and after being kindled, introduced into a vase of the gas.

In all of these experiments, the sulphur unites with oxigen; but the proportion varies according to the mode of combustion. When burning slowly, it forms a compound called *sulphurous acid*, better known by the name of fumes of sulphur, and when the heat is high, *sulphuric acid*, or oil of vitriol, is produced. *(See Acids.)*

Sulphur combines with different proportions of hydrogen. When kept together at a natural temperature, there is no action; but if heat be applied, they unite, and form a gaseous fluid, called *sulphuretted hydrogen*, and they may

be made to combine in other proportions, and form an oily-looking substance. Both of these are acids, and will be afterwards described.

The action between sulphur and carbon is interesting, as affording a fluid possessed of very remarkable properties. Lampadius, in 1796, (Crell's Annals, 1796, ii. 136.) when subjecting to heat charcoal and a compound of sulphur, obtained a fluid which he described under the name of *alcohol of sulphur*, and which he inferred, from his experiments, was a compound of sulphur and hydrogen, an opinion adopted also by the younger Berthollet, (Mem. d'Arcueil, i. 304.) It was afterwards examined by Cluzel, who proved it to be a compound of sulphur and carbon, (An. de Chimie, lxxxiv. 72.) and which has been confirmed by Berzelius and Marcet, (Ph. Trans. 1813.) It has now received the name of

Sulphuret of Carbon.

Clement and Desormes have pointed out an easy method of obtaining it. For this purpose, a porcelain tube, stuffed with charcoal, is passed through a furnace, and brought to a red heat. To one end is fixed a vessel with chips of sulphur, and furnished with a wire to push them into the tube; to the opposite one is adapted a bent glass tube, which is made to terminate in a bottle of water, taking care that there is not as much in the phial, as, in the event of condensation, will rise into the porcelain one. When the tube has become red hot, heat is applied to the sulphur, so as to melt it, and cause it to flow upon the charcoal, and the moment they come in contact they unite, and pass off in the state of vapour, which, escaping through the glass tube into the water, is condensed in the form of an oily-looking fluid, of a yellowish colour. To free it from impurities, it must be put into a retort, and distilled by a heat not exceeding 110. A transparent colourless liquid is collected in the receiver, which is the sulphuret pure.

Sulphuret of carbon has an acrid pungent taste, and a

fetid disagreeable odour. According to Cluzel, its specific gravity is 1263; according to Marcet 1272. When heated, it boils at about 110; but by the abstraction of caloric, it has not yet been made to undergo any change. It is one of the most volatile fluids with which we are acquainted, and produces, by its evaporation, an intense degree of cold. When the bulb of a thermometer, covered with muslin, is dipt into it, and then whirled in the air, the temperature falls from 60 to about 0. If the sulphuret be allowed to fall, drop by drop, on the thermometer, placed under the receiver of a pump, and the air quickly withdrawn, the cold will be about —80, in less than two minutes. The vapour, however, is very apt to injure the valves of the pump.

When the sulphuret is heated in air, it takes fire; but the temperature at which it is inflamed, has not been accurately ascertained; it is not high, however, probably not exceeding 700. The flame is blue, and the vapour formed has the odour of burning sulphur.

When electric sparks are passed through the vapour of the sulphuret, mixed with oxigen, they detonate, and, provided there is a sufficient quantity of the latter, sulphurous acid and carbonic acid are the products.

It is very sparingly soluble in water. Berthollet, Thenard, and Vauquelin, succeeded in decomposing it, by passing its vapour through incandescent tubes, containing a metal; and Berzelius, by a similar method, ascertained the proportions of the ingredients. According to him, it is composed of

Sulphur, 84.83
Carbon, 15.17

And as 15.17 : 84.88 :: 7.5 : 41

So nearly 40 that it may be considered a *Bi-Sulphuret*, and therefore composed of

1 atom of carbon, - -	7.5
2 atoms of sulphur, - -	40.
and its atomic weight is - - -	47.5

Sulphur acts very easily with phosphorus, provided the temperature is a little elevated. The compound was first pointed out by Margraaf, and afterwards examined by Pelletier, (Journ. de Phys. xxxv.); but more particularly by Dr Briggs, (Nicolson's Journ. vi.) who has pointed out different methods of preparing it. The union may be effected merely by heating them, but which must be done under water, to prevent combustion, and the heat must be applied cautiously, otherwise there is a generation of gas from the decomposition of the fluid, and which is apt to cause explosion. Using about equal weights, or, which is probably better, 15 of phosphorus to 20 of sulphur, and which is the atomic proportion, the compound is of a yellowish colour, and easily fused. When heated in water to about 210, there is a decomposition, and formation of phosphuretted and sulphuretted hydrogen gases. When exposed to the air, it instantly takes fire, and hence its use in affording a light.

For preparing the instantaneous light-giving bottles, a piece of phosphorus well dried is put into a quarter of an ounce phial, with about an equal weight of the flowers of sulphur, and then well corked, and set aside for a few days, to allow them to unite. When a light is required, a little of the product is brought out by a common sulphur match, on which, when exposed to the air, it is kindled, and sets fire to the sulphur. In using these bottles, the cork must be left out as short a time as possible, to prevent the mixture from absorbing air, by which it may be inflamed. They may also be more quickly prepared, by putting the phial with the mixture into warm water, so as to melt the phosphorus, and cause it to act on the sulphur; but, as has been already mentioned, unless very cautious in heating it, the mixture is apt to take fire, so that the other, if not required for immediate use, is preferable.

Sulphurets of Arsenic.

Sulphur unites with arsenic, and forms substance

long known by the names of *orpiment* and *realgar*, both of which are native productions; but they may also be formed artificially, the latter by heating sulphur and arsenic, or its compound with oxigen, arsenious acid, and the former by the addition of sulphuretted hydrogen to an arsenical solution. These were at one time supposed to differ in their composition, one being considered a sulphuret, the other a compound of sulphur and arsenic in the state of oxid; but this has been disproved by the experiments of Laugier, who has shewn that they both contain arsenic free from oxigen, but differing in its proportion.

The ingredients are,

In Realgar, arsenic 100, sulphur 43.67,
Orpiment, — 100, — 63.93.

Now as 100 : 43.67 : : 47.5 : 21

So nearly 20, that we may consider the first a compound of

1 atom of arsenic,	47.5
1 atom of sulphur,	20.
	67.5

And is therefore a *proto-sulphuret*. But in the second, the sulphur is not a multiple of that in the other; it is, however, very nearly one-half more; so that, if we suppose it a half, then it is a *sesqui-sulphuret*, or it may be considered a compound of

2 atoms of arsenic,	95
3 atoms of sulphur,	60
	155

Realgar is much employed in dyeing, being used for de-oxidizing indigo, and allowing it to become fixed on cloth.

Sulphur is found in abundance in the mineral kingdom, both combined and in its free state. It exists in all volcanic countries, as Italy, Sicily, and Iceland, which supply the most part of Europe with it. It is found also in great abundance in union with many of the metals, as

iron, copper, and lead. Different methods are followed for procuring it, according to the state in which it exists. When it is combined with earthy matter, as in volcanic productions, it is exposed to heat, in large pots, well covered, to prevent the admission of air; when fluid, the impurities fall to the bottom, and it is then poured into moulds, thus forming the cylinders. If the foreign matter should not separate in this way, a greater heat is applied, and the sulphur is sublimed, the process being conducted in pots having receivers adapted to them, in which the vapour is condensed. In procuring metals from their compounds with sulphur, they are exposed to heat, by which sulphur in vapour is given off, and condensed in chambers connected with the vessel, in which the metallic compound is heated. By both of these processes, the *flowers* are obtained.

The uses of sulphur are numerous and important. It is consumed largely in the formation of oil of vitriol, and in the manufacture of gunpowder, in both of which it is used along with nitre. *(See Nitre.)*

It is employed also in medicine internally, as a gentle laxative, and externally, in conjunction with lard, as an ointment in cutaneous diseases, particularly itch, in which it seems to exert some specific action.

CHLORINE.

When muriatic acid is poured on some bodies that contain oxigen, a gaseous fluid of a yellowish colour is disengaged, which was long considered a compound of muriatic acid with an additional proportion of oxigen, derived from the other substance, and hence its names, *oxigenized* and *oxi-muriatic acid.* It is now, however, almost universally admitted, that the gas is a simple body, being derived from the muriatic acid, in which it exists in union with hydrogen. This view of its nature was first thrown out by Gay Lussac and Thenard, (Recherches Phys. Chim. 1811.); but they did not maintain it, as they did not think it probable, being so

completely at variance with the Lavoiserian doctrine with respect to acidity ; that it depended on the presence of oxigen. Sir H. Davy, however, afterwards asserted that this was really the composition of the acid, and that the yellow gas must be considered a simple body, and of course another acidifying principle. He gave it the name of Chlorine from its greenish yellow colour, (from χλωρος, *green*,) Phil. Tr. 1810.

Though the simple nature of chlorine is now almost universally admitted, yet the supporters of this doctrine are not agreed with respect to the place it should hold among other simple bodies ; for there are many who, instead of considering it as the acidifying principle in those acids not containing oxigen, are inclined to look on it as the base, and attach a principle of acidity to hydrogen. From the arrangement I have adopted, it will be observed that I am of the latter opinion ; and it is from the great resemblance between it and sulphur, in most of its qualities, that I have thought proper to bring them under the same class *.

Chlorine was discovered by Scheele, when examining the nature of the black oxid of manganese, the substance always used in its preparation. *(See Manganese.)* It has since been examined by Berthollet, Sir H. Davy, Dr Murray, Dr Davy, and indeed by almost all the chemists of distinction of the present time.

Chlorine is of a greenish yellow colour, has a peculiar offensive odour, and is extremely irritating to the eyes, nostrils, and lungs. When breathed pure it instantly proves fatal, and even when largely diluted with air, it excites severe coughing, followed by headache, deep pain of the chest, and general derangement of the system, which continue for a considerable time ; and hence the necessity of great caution when experimenting with it. It is consi-

* For a full account of the opinions entertained with respect to the nature of chlorine, and of the experiments by which the supporters of the different doctrines endeavoured to establish their truth, the reader is referred to the papers of Sir H. Davy, Dr Murray, and Dr Davy, in Nicolson's Journal, vol. xxxiv. Ed. Ph. Tr. vol. viii. An. of Phil. xii. xiii.

derably heavier than air, but its specific gravity has been variously stated. It is now allowed to be 2500. Its atomic weight 45.

Chlorine possesses the very remarkable property of destroying the colour of almost all vegetable, and also of many animal and mineral substances,—a property which is most easily shewn with its solution.

It is not altered by heat, light, or electricity, provided it is quite dry.

Water very easily absorbs it, the quantity depending on the temperature and pressure. At 50 it takes up about twice its own bulk of it; and if reduced to 40, soft scales are formed, which, from their quantity, make the solution almost concrete, as may be shewn by collecting the gas in jars filled with ice-cold water. If a little water be admitted into a bottle of gas, and kept at a temperature below 30, dendritic crystals are formed, which may be made, by the approach of the hand, to sublime from one part to another. These, according to Faraday, are a *hydrate of chlorine*, in the proportion of

Chlorine 27.7
Water 72.3

And as $27.7 : 72.3 :: 45 : 113$

And $\frac{113}{10} = 11.3$

So that it is probably a compound of

1 atom chlorine 45.
10 atoms water 112.5

And its atomic weight will be 157.5

It was with this substance that he succeeded in procuring chlorine in the fluid form, and which was done by putting it into a strong bent glass tube, and then sealing it hermetically. On the application of a slight heat it was volatilized, and two fluids were condensed in the cold end, the one of a pale yellow colour, the other, which lay below it, of a dark yellow, and having no tendency to mix with it. By the cautious application of heat, they were separated, and, on breaking under water the end

containing the latter, it instantly disappeared, and chlorine gas was given off, (Phil. Tr. 1823.)

The solution of chlorine in water, and which is easily prepared by shaking them in a phial together, is yellowish, has the offensive smell of the gas, and possesses in a remarkable degree the power of destroying colour. Thus, if a little be added to red cabbage water, to litmus water, or to infusion of cochineal, the colour instantly disappears, and, what is very remarkable, it cannot be recalled by any other agent. If the colour has been imparted to cloth, it cannot resist the action of the solution; a few pieces of printed calico immersed in it becoming white, the time required depending on the nature of the dye-stuff.

Though the solution thus acts so easily on colour, it is necessary to employ it when recently prepared, as it undergoes decomposition, particularly when exposed to light; the hydrogen of the water uniting with the chlorine, to form muriatic acid, and oxigen gas being liberated, so that instead of banishing the colour, it will change it to red. This points out, also, the necessity of keeping the solution in the dark, or in earthenware bottles.

Chlorine has no direct action with oxigen, but they can be made to enter into union, and form no less than four distinct compounds, two of which are gaseous, and are considered oxids, the others are acids.

Protoxid of Chlorine, or Euchlorine.

This gas cannot be prepared by the direct union of its ingredients; we are obliged, therefore, to have recourse to decomposition. The substances from which it is prepared, are muriatic acid, and chlorate of potassa. (*See Chlorate of Potassa.*)

It was discovered in 1811, by Davy, (Phil. Tr. 1811,) who gave it the name of *Euchlorine*. It is of a much darker yellow colour than chlorine, and has, like it, a very offensive smell, being also extremely irritating. Its specific gravity is 2444, and its atomic weight 55.

When subjected to strong pressure, it becomes a deep yellow fluid, remaining so at —40, and which, when exposed to the atmosphere, instantly flies off in gas.

Euchlorine freed from water, at first gives a reddish tint to vegetable blues, but soon destroys the colour. It is unfit for the support of respiration.

Its most remarkable property is its exploding by the application of a slight heat, and hence, of course, great caution is necessary when experimenting with it. The easiest mode of exploding it, is to hold a small phial of it, loosely corked, over the flame of a spirit-lamp, by which it is decomposed, and resolved into its component parts, chlorine and oxigen; at the same time heat and light are evolved, and there is an expansion, 5 parts becoming 6. This is considered a very remarkable case of chemical action, as in almost all instances of the evolution of heat there is a condensation of the substances employed, which is supposed to be the cause of the evolution.

The action of the oxid with inflammables is not violent. When mixed with hydrogen and heated, it explodes, and liquid muriatic acid is formed, part of the hydrogen uniting with the oxigen to produce water, the remainder with the chlorine to form the acid.

When phosphorus is introduced into it, it is inflamed, and the same compounds are formed as when burned in a mixture of chlorine and oxigen. When charcoal in a state of combustion is put into it, there is a brilliant flash, and it then burns with a dull red light.

Though protoxid of chlorine thus acts with so much ease with inflammables in general, yet it is remarkable that it does not act on some of those that are easily inflamed by chlorine. Thus, when copper leaf is put into it, there is no action, but if heat be applied so as to cause explosion and separation of ingredients, there is an immediate action on the metal, the chlorine inflaming it.

Euchlorine is absorbed by water, which takes up about 8 or 10 times its own volume of it.

According to Davy it is composed of

	Vols.		By weight.
Chlorine, - -	2	=	5000 or 81.82
Oxigen, - - -	1	=	1111 or 18.18

and as 81.82 : 18.18 : : 45 : 10.

So that it is a compound of

1 atom chlorine, -	45
1 atom oxigen, -	10
and its atomic weight is	55

As the atom of oxigen is represented by 1 volume, and euchlorine is a protochlorid, that of chlorine must be represented by 2 volumes.

It has been already mentioned, that by explosion, 5 volumes become 6, that is, 2.5 become 3, and which consist of 2 of chlorine, and 1 of oxigen; so that in euchlorine, the oxigen is condensed into half its original volume; in other words, euchlorine is composed of

Vols.		Vol.
chlorine,	2 }	condensed into 1.
oxigen,	1 }	

If so, its specific gravity must be

$$2500 \times 2 = 5000 + 1111 = \frac{6111}{2.5} = 2444,$$

the number formerly stated.

Peroxid of Chlorine.

Peroxid of chlorine cannot be procured by the direct union of its component parts. We are obliged, therefore, to have recourse to decomposition, and for this purpose, chlorate of potassa is decomposed by sulphuric acid. *(See Chlorate of Potassa.)*

It was discovered nearly about the same time by Davy, and Count Von Stadion of Vienna, the former of whom gave an account of it, in Phil. Tr. for 1815.

It is a gaseous fluid, of a dark yellow colour, having a peculiar aromatic odour. Its specific gravity is 2361, and its atomic weight 85. Water absorbs about 7 times its volume; the solution has the colour of the gas, and has an astringent taste, leaving a disagreeable sensa-

tion on the tongue. It destroys vegetable colours, without previously reddening them.

When heated to about 112, it explodes with considerable violence; indeed, so much so, that the experiment is dangerous, unless performed on a small quantity, and in strong tubes. During the explosion, heat is disengaged, and there is a brilliant flash of light; and as with the protoxid, there is an expansion, 4 volumes becoming 6, which contain 4 of oxigen, and 2 of chlorine. Its composition is, therefore,

	Vols.	By weight.
chlorine,	2 = 5000	or 52.97
oxigen,	4 = 4444	or 47.03

and as 5000 : 4444 : : 45 : 40

So that it is composed of

1 atom of chlorine, -	45
4 atoms of oxigen, -	40
and its atomic weight is	95

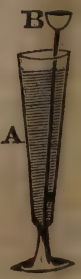
Its composition may be stated also to be

	Vols.	
chlorine,	2	condensed into 4.
oxigen,	4	

So that the condensation is equal to the volume of the chlorine, and if so, its specific gravity must be

$$\frac{5000 + 4444}{4} = 2361$$

The action of peroxid of chlorine with inflammables is by no means violent, except with phosphorus, with which it explodes with great force, indeed so much so, that the experiment is attended with danger, unless performed on very minute quantities, or some means be taken to prevent the action from going on too rapidly. The safest method of shewing the action, is to put at the bottom of a glass of water, A, about 10 grains of the chlorate of potassa, the salt from which the peroxid is procured, along with some chips of phosphorus, and then pour in, through a long funnel, B, a few drops of sulphuric acid, which, by its weight, falls, and



comes in contact with the salt, without mixing with the water. The moment it does this, it acts on it, setting free the gas, which inflames the phosphorus, so that each bubble that comes off is decomposed, and there is therefore no risk of any accident. The products are the same as when the phosphorus is heated in a mixture of chlorine and oxigen.

Chlorine unites with at least two other proportions of oxigen, but as the compounds are acid, they will be considered afterwards.

Chlorine acts in general with great ease with inflammables, many of which it inflames, without the application of heat, but the combustion is by no means lively, not nearly so much so as in atmospheric air.

When hydrogen is mixed with chlorine, there is no action, at a natural temperature, provided they be excluded from light; but the moment that heat is applied, they explode. For this purpose, the common exploding bottle may be used, employing equal volumes of the gases. If they be mixed, and exposed to light over water, there is a gradual condensation, and consequent rise of the water, which, if the gases are pure, will fill the jar. When the mixture is exposed to the direct rays of the sun, instead of a slow action, there is an instant explosion. In all of these cases, the chlorine and hydrogen unite, and form an acid; and that they do so, is evident, by adding cabbage infusion to the water in the jar. It is reddened, shewing not only the formation of acid, but also the complete change of the properties of the chlorine. The compound formed, has been long known by the name of *muriatic acid.* It will be afterwards described.

Chlorid of Nitrogen.

Chlorine and nitrogen do not act when presented to each other in the gaseous form, but they can be made to enter into union by indirect means, and form a sub-

stance possessed of very remarkable properties, and which has been called *chlorid of nitrogen.*

It may be prepared by passing a stream of chlorine, through a solution of any ammoniacal salt, or through that of ammonia itself, which is a compound of hydrogen and nitrogen. A preferable mode of preparing it, is to fill a common soup-plate with a solution of muriate of ammonia, heated to about 100, and over this is to be placed a jar of chlorine gas, resting on a piece of lead, with a depression in it to collect the product. The gas slowly disappears, and a thin film of a brown oily-looking fluid is formed on the surface of the solution, and collecting into globules, falls into the leaden cup. In this experiment all the apparatus must be perfectly clean, particularly free from any greasy matter, and the action must be allowed to go on slowly When prepared, the jar must be removed, and experiments performed on it in the cup; or it may be got pure, by drawing off the water cautiously, with a little bibulous paper; but for most experiments there is no necessity for this.

Chlorid of azote, was discovered by Dulong in 1812, (Ann. de Chim. v. 85.) who was severely injured by it, so much so, as to prevent him prosecuting the investigation of its properties. Davy, who had been previously informed of this discovery, afterwards prepared it, and examined a few of its qualities, (Ph. Tr. 1813.); but the fullest account of it yet published, is by Porret, Kirk, and Wilson, (Nicolson's Journal, March 1813.)

It is a brownish oily-looking fluid, of specific gravity about 1653. It has a peculiar penetrating odour, and evaporates quickly on exposure to the atmosphere. *In vacuo* it speedily passes off in vapour, and is again condensed as air is admitted. By the application of caloric to it in close vessels, it evaporates at 160, and at a little below 212, it explodes with tremendous force, the products being chlorine and nitrogen. It has been subjected to a temperature —16, without congealing. When left in water it soon disappears, and azote is generated.

The most remarkable property of chlorid of azote, is

its prodigious exploding power when touched with any oily matter, the smallest quantity acting with such force as to break the vessels, if of glass or earthenware. The safest mode of exploding it, is to keep it on the leaden cup, and *after removing this from the plate*, without drawing off the water, to touch it with a piece of cane dipt in oil, and held loosely in the hand. The product of the action of 8 or 10 ounce measures of chlorine, and which will afford a globule of about the size of the fourth of a garden pea, is sufficient; indeed it is dangerous to use more. This, and the ease with which it is decomposed by heat, shew the necessity of extreme caution when experimenting with it; indeed, the operator ought always to wear a mask, as even with all precautions, it sometimes explodes without any apparent cause.

It is also easily exploded by other bodies, as phosphorus, turpentine, caoutchouc, and many other compound inflammables. Metals and resins have no action with it.

It has been already mentioned, that the only products of its explosion are, according to Davy, chlorine and nitrogen; but Porret, Kirk, and Wilson, assert that it contains also a little hydrogen, which acts as a medium of combination of the others. Davy succeeded, however, in decomposing it by mercury, which absorbs the chlorine, and disengages the nitrogen.

From these, and other experiments, it is considered a compound of

4 vols. chlorine,
1 azote.

Its component parts, by weight, must therefore be,

sp. gr. ch. $\times$ 4 = 10,000 + sp. gr. az. = 972.

And as 972 : 10,000 : : 17.5 : 180

And $\frac{180}{4} = 45$.

So that it is a compound of

1 atom azote,	17.5
4 atoms chlorine,	180.
And its atomic weight is	197.5

Considering this as its composition, we can easily account for its formation. Ammonia, it has been mentioned, is a compound of nitrogen and hydrogen, in the ratio of 1 atom of the former to 3 of the latter. If we suppose, then, that 7 atoms of chlorine are employed, 3 of these will unite with the 3 of hydrogen to generate muriatic acid, while the remaining 4 will combine with the 1 of nitrogen to produce the chlorid.

Protochlorid and Perchlorid of Phosphorus.

Chlorine combines with phosphorus, and forms two compounds.

When a small piece of phosphorus is introduced into a jar of chlorine, it immediately takes fire, and burns with a feeble flame. A white substance is formed, which in general adheres to the vessel. If the phosphorus be in larger quantity, a fluid is also produced, which trickles down the sides; the latter is the protochlorid, the former perchlorid.

Perchlorid of Phosphorus, the concrete matter formed by the combustion of phosphorus in chlorine, is white and very volatile, rising in vapour at a temperature below 212. When thrown into water, both are decomposed, the hydrogen uniting with the chlorine, and the phosphorus with the oxigen, and muriatic and phosphoric acids are the products *. According to Davy, 100 of phosphorus combine with 600 of chlorine, by weight, in the formation of this chlorid: now

$$100 : 600 :: 15 : 90, \text{ and } \frac{90}{2} = 45.$$

So that it is composed of

* It may be considered as a general rule, that when a chlorid disappears on being thrown into water, *the hydrogen unites with the chlorine to form muriatic acid, and the oxigen with the other substance to generate either an acid or an oxid*, just as that substance will form, by its union with oxigen, an acid or an oxid. If an oxid be produced, it unites with the muriatic acid, and forms a salt called a *Muriate*.

Phosphorus	1 atom,	15
Chlorine	2 atoms,	90
and its atomic weight will be		105

Though *Protochlorid of Phosphorus* can be procured by the direct union of its ingredients, a better mode of preparing it is that pointed out by Davy, (Phil. Tr. 1812.) which consists in passing the vapour of phosphorus over corrosive sublimate, or perchlorid of mercury, (a compound of 1 atom of mercury and 2 of chlorine,) by which the phosphorus unites with 1 atom of the chlorine to form the protochlorid, leaving the mercury still in union with the other. The product is a transparent colourless fluid, of sp. gr. 1450. It may be kept any length of time in close vessels without undergoing a change, but on exposure to air, part flies off, and leaves phosphorus behind. It dissolves phosphorus, and on exposing the solution to air, it is also quickly evaporated, and the phosphorus left is inflamed; and hence its use as a means of affording light. When thrown into water, both are decomposed, and muriatic and phosphorous acids are formed.

Protochlorid of phosphorus contains exactly half the quantity of chlorine that exists in the former; so that it is composed of

Phosphorus	1 atom,	15
Chlorine	1 atom,	45
and its atomic weight is		60

In the decomposition of water by the chlorids of phosphorus, the products must of course vary according to the proportions of the ingredients. When protochlorid is used, as it and the water contain an atom of each of their ingredients, they will again combine, atom to atom, the hydrogen and the chlorine to form muriatic acid, the phosphorus and oxigen, phosphorous acid, or the compound with the smallest proportion of oxigen. When perchlorid is used, which contains 2 atoms of chlorine in union with 1 of phosphorus, a compound of phosphorus,

with double the quantity of oxigen, must be generated, because the two of chlorine will take two of hydrogen to form two atoms of muriatic acid, thus decomposing 2 atoms of water, and by which 2 of oxigen will be disengaged, to unite with the phosphorus to produce phosphoric acid.

Though chlorine acts with such ease on inflammables in general, it is remarkable that there is no action between it and charcoal, provided they are pure, particularly free from water. Even at a high temperature they do not act. Thus, in passing the gas through an incandescent tube, stuffed with charcoal, it comes out unchanged; or if a piece of charcoal, in a state of combustion, be put into the gas, it is instantly extinguished. Though they do not unite directly, yet they can be made to enter into union by indirect means, and form

Chlorids of Carbon.

When chlorine and olefiant gas, or bi-hydroguret of carbon, are mixed over water, they gradually disappear, and an oily-looking fluid collects on the surface, from which circumstance the latter has derived its name. In performing this experiment, there should be rather less chlorine than of the other, because, when in excess, it is apt to dissolve the product.

Mr Faraday has made this substance the subject of investigation, and shewn that a chlorid of carbon can be got from it, (Ph. Tr. 1821.) He supposes that it is a compound of chlorine, carbon, and hydrogen, the two last derived from the olefiant gas; and that, by adding more chlorine, it unites with the hydrogen, and leaves the others in union. For preparing the chlorid, chlorine and olefiant gases are thrown in, one after the other, into an exhausted flask, till a sufficient quantity of the fluid is collected; taking care to leave an excess of the former, so that, on exposure to the sun's rays, it will unite with the hydrogen, and form muriatic acid, which will be absorbed on the admission of a little water. Minute crys-

tals of the chlorid are gradually formed, which may be purified by sublimation, then dissolving it in alcohol, and adding potassa to remove any adhering muriatic acid, and by which, at the same time, it is precipitated.

The substance thus prepared, and which is a *perchlorid*, is a whitish powder, of the sp. gr. about 2000. It fuses at 320, and boils at 360; and on becoming solid it assumes a crystalline appearance. When heated in oxigen gas, it burns with brilliancy. It is decomposed by sulphur and phosphorus, which unite with part of its chlorine.

Faraday succeeded in decomposing it, by passing it over peroxid of copper, and from his experiments he concludes that it is composed of

Carbon 10.7
Chlorine 89.3

And $10.7 : 89.3 :: 15 : 135$

But $\frac{15}{2} = 7.5$, and $\frac{135}{3} = 45$.

From which it appears to be composed of

3 atoms of chlorine -	135
2 atoms of carbon -	15
Its atomic weight being	150

When this perchlorid is passed through an incandescent tube, stuffed with pieces of rock crystal, it is decomposed, part of the chlorine is given off, and the remaining ingredients are left in union, and come over in the form of a transparent colourless fluid, the sp. gr. of which is 1552. It is insoluble in water, but is dissolved by alcohol. By the application of heat, it evaporates at about 160.

It is composed of

1 atom chlorine,	45.	or	85.7
1 atom carbon,	7.5	or	14.3
Its atomic weight being	52.5		100.

There is still another compound of carbon and chlorine, which was discovered by Julin, (An. of Phil. N. S. i.) when distilling nitric acid from a mixture of crude

nitre and sulphate of iron. According to Faraday, it is composed of

1 atom chlorine,	45
2 atoms carbon,	15
And its atomic weight is	60

But its proportions have not been examined *.

Chloro-Carbonic Gas.

Chlorine acts easily with carbonic oxid. Provided they are exposed to sunshine, a gaseous fluid is formed, which was discovered by Dr Davy, and called by him *Phosgene Gas*, from its being procured by the action of light. It is prepared by receiving into an exhausted flask equal parts of well-dried chlorine and carbonic oxid, and exposing them to sunshine, by which they combine, and form a compound occupying half the original bulk of the gases.

It is a transparent colourless gas, having a pungent odour, and being very irritating to the eyes. Its specific gravity must be 3472.

Chlorine 2500 + Carb. Ox. 972 = 3472.

Water absorbs it, but, at the same time, decomposes it, forming carbonic and muriatic acids, the atom of hydrogen uniting with the chlorine, and the oxigen with the oxid. Though this gas was called by its discoverer Phosgene Gas, yet others are inclined to consider it an acid,

* In the compounds of chlorine and carbon, we have an illustration of the remarks made (p. 155.) with respect to substances combining apparently not in multiple proportions. In the chlorid discovered by Julin, the ingredients are atom to atom; in that obtained by the action of chlorine on olefiant gas, they are 2 to 3, and in the other 1 to 2; so that they are,

1st,	Carbon	7.5	Chlorine	45.
2d,	Do.	7.5	Do.	67.5
3d,	Do.	7.5	Do.	90.

Now the chlorine in the second is not a multiple of that in the first; but it is probable that this is a compound of 1 atom of protochlorid, and 1 atom perchlorid; so that, when analyzed, it will yield 2 of carbon and 3 of chlorine, and which makes it appear to contain 1 to 1½.

If this view of its composition is correct, the compounds of chlorine and carbon are not exceptions to the rule of multiple proportions.

and propose to call it *Chloro-Carbonic Acid.* If so, it may probably belong to the class of acids containing compound bases, as cyanogen and xanthogen, the chlorine and carbon in union acting as the radical; but our knowledge of its properties is too limited to warrant any conclusion of the kind.

Chlorid of Sulphur.

When sulphur is put into chlorine gas, there is little or no action at a natural temperature; but on the application of heat, it rises in vapour, and is condensed in the form of a reddish powder. To cause them to unite, the gas must be passed through the sulphur in the state of flowers, by which a liquid is formed, of a reddish brown colour when viewed with reflected light, but yellowish with transmitted light. Its specific gravity is 1623. It is volatile, and exhales a pungent irritating vapour. Its taste is bitter, causing a tickling sensation in the throat. When thrown into water, sulphur is deposited, and sulphurous and muriatic acids are formed, the hydrogen uniting with the chlorine, and the oxigen with the remainder of the sulphur. This substance, though at first considered by Thomson, who discovered it, as a compound of sulphur and muriatic acid, is now allowed to be a chlorid of sulphur.

Davy found that 100 of sulphur absorbed 300 cubic inches of chlorine, weighing 228.7 grains.

And as 100 : 228.7 : : 20 : 45.7.

So that we may consider it composed of

1 atom of chlorine,	45
1 atom of sulphur,	20
Hence its atomic weight is	65

Chlorine was recommended by Morveau for destroying the virulence of contagious effluvia; for which purpose, when the apartments are empty, it may be employed with great efficacy, but from its irritating nature, it is impossible to use it when the sick are in them. It is now, however, employed in union with lime for this purpose. *(See Lime.)*

Its solution in water has been recommended, and indeed said to be used with the utmost success, in scarlet fever. From its remarkable property of destroying colour, it is now much employed in bleaching; but for this purpose, it is always in a state of combination with lime. *(See Lime.)*

In explaining the actions of chlorine with other substances, it has been all along considered as a simple body, entering into union with others, and forming either acids or chlorids. It has been already mentioned, that another opinion is still entertained with respect to its composition. It is supposed that muriatic acid is a compound of a base not yet discovered, and oxigen, and that chlorine may be a compound of this acid with an additional proportion of oxigen, and hence its name, *oximuriatic acid.* If so, we can easily account for its action with other substances. Those compounds called chlorids by the supporters of the new doctrine, must be considered by the others as containing muriatic acid, and a compound of oxigen and the body presented to the action of the gas. Thus, when sulphur and the gas act, the sulphur unites with the excess of oxigen, to form sulphuric acid, while the gas, deprived of its excess of oxigen, becomes muriatic acid.

When the gas and hydrogen are mixed, by which, according to the new doctrine, there is merely combination and generation of muriatic acid; according to the old one, the gas parts with its excess of oxigen to the hydrogen to form water, and muriatic acid is left, with which the water unites. Should the substances presented to the gas form an oxid, then by its union with the excess of oxigen the oxid is produced, which combines with the muriatic acid, and generates a muriate. Again, when the gas is acted on by a compound inflammable, as olefiant gas, part of the excess of oxigen must unite with the hydrogen to generate water, another part with the carbon to form carbonic acid, while by the loss of the oxigen, muriatic acid is produced; so that the compound, chlorid of carbon of the new, is muriatic and carbonic acid of the old doctrine.

IODINE.

Iodine was discovered by M. Courtois, a manufacturer of saltpetre in France, while endeavouring to ascertain the cause of the erosion of the iron vessels employed in the process for extracting alkaline matter from kelp. He gave some of it to Clement, who examined it, and read an account of it to the French Institute in 1813. Its properties were afterwards more fully investigated by Gay Lussac and Vauquelin, (An. de Chimie, 90, 91.) and by Sir H. Davy, (Phil. Tr. 1814.)

It has received its name from ιωδης, *violaceous*, the colour of its vapour. It is always procured from kelp, the product of the combustion of sea-weed, and in which it exists in union with hydrogen, forming an acid now called hydriodic acid. *(See Hydriodate of Potass.)*

Iodine, as usually procured, is in the form of small thin plates, of a dark colour, and metallic splendour, somewhat resembling black lead. It has a pungent disagreeable odour, similar to that of chlorine, and an acrid taste. Its specific gravity is 4946, and its atomic weight 155. It is a non-conducter of electricity. When put on the skin it leaves a brown stain, but which disappears in the course of a short time. Like chlorine, it has the power of destroying colours, though in a much less degree. It is very sparingly soluble in water, requiring about 7000 parts at a natural temperature. The solution is of a brown colour, and has the peculiar odour of the iodine itself.

When iodine is exposed to heat it melts at 225, and at 350 it passes into the state of vapour of a beautiful violet colour, and which condenses in the cool part of the apparatus in slender dendritic crystals. This experiment is most easily performed by putting a few grains of the substance into a flask, which may be then tightly corked and held over a chauffer so as to heat the whole of it; and as there is no waste, the conversion into vapour may be repeated as often as we please.

The specific gravity of the vapour is 8611, compared to air as 1000, at the usual pressure and temperature.

Iodine has no direct action with oxigen; it does not even unite with it when heated in it; but they can be made to combine, and form compounds possessed of acid properties, which will be afterwards described. The same is the case with hydrogen, the union being effected by indirect means, and by which acid compounds are formed.

Iodid of Nitrogen.

When iodine is kept in nitrogen, they do not unite; but by exposing it to the action of substances containing it, a detonating compound can be formed. For this purpose, a few grains of iodine are put into water of ammonia, which consists of hydrogen and nitrogen, and which is gradually decomposed, the iodine and nitrogen uniting to form an iodid. Or it may be procured by using chlorid of iodine, instead of pure iodine, by which there is a double decomposition, the chlorine combining with the hydrogen of the ammonia, to form muriatic acid, and the iodine with the nitrogen, to generate the chlorid. After it is formed, the fluid must be poured on a filter, on which the iodid can be collected, and dried by exposure to air.

Iodid of nitrogen, as thus procured, is a powder of a brownish colour, which, on exposure to air, flies off in vapour. When subjected to heat, it detonates, though feebly; and if the experiment be performed in an exhausted flask, the only products are iodine and nitrogen, but the proportions have not yet been ascertained.

Iodid of Phosphorus.

Iodine combines with phosphorus, and forms an iodid. To procure it, 1 of phosphorus is mixed with 10.5 of iodine in a small tube. They combine, at the same time giving out heat, and a brown matter is formed, which

fuses at 212, and flies off in vapour, at a temperature a little higher. When thrown into water, there is a double decomposition, and hydriodic and phosphorous acids are produced, so that the hydrogen unites with the iodine, and the oxigen with the phosphorus. If double the quantity of iodine be employed, the union is also attended with the evolution of caloric, and a dark-coloured compound is formed, which is likewise decomposed by water, hydriodic and phosphoric acid being the products.

Iodid of Sulphur.

Iodine easily unites with sulphur. The union may be effected by heating them together in a tube, by which, when the sulphur is melted, a substance of a dark grey colour is formed, which is decomposed by heat, the iodine being driven off in vapour. When thrown into water, it is decomposed, and iodine is deposited. The proportions of its ingredients have not been ascertained.

Chlorid of Iodine.

When iodine is put into chlorine gas, there is a gradual absorption, and production of a dark-coloured compound, which, when thrown into water, forms a brown solution, but which by the transmission of chlorine gas becomes colourless. Some have supposed that the compound thus formed, is an acid, and have given it the name of *chloriodic acid;* while others maintain that it is an iodid, and that when thrown into water there is a double decomposition, the iodine uniting with the oxigen to form iodic acid, and the hydrogen with the chlorine to generate muriatic acid. This opinion is strengthened by the fact, that when the solution is treated with salifiable bases, salts containing iodic acid are formed.

Iodine acts in a peculiar way with sulphuret of carbon. When its solution is added to the sulphuret, globules of a pink-coloured fluid are formed, which fall to the bottom of the glass, and at the same time the colour

of the iodine solution disappears. The nature of this substance has not yet been ascertained, but the action is important, as affording an excellent test of the presence of iodine, provided of course it is in its uncombined state.

Iodine acts also with starch. When their solutions are mixed, a blue precipitate is formed, but which is re-dissolved if the starch is in excess. The ease with which these substances act, affords another excellent test; indeed it is so delicate, that the fluid will acquire a blue tinge, though it does not contain more than 1-450,000th part of iodine, and provided it is in its uncombined state. It frequently happens, however, that iodine exists in combination, as in the form of an acid; and when this is the case, the starch will not act on it, but it may be made to do so by the addition of other re-agents. Suppose it in this state, the solution must be mixed with that of starch, after which an aqueous solution of chlorine is poured on cautiously, so as to keep it floating on the other, and in the course of a short time, a blue tinge appears where the fluids are in contact, the chlorine depriving the iodine of the substance with which it was in union, and thus enabling the starch to act on it.

Another method of detecting iodine with starch, is by the action of sulphuric acid. When, for instance, it is in such a state of combination that the starch does not act on it, a drop of sulphuric acid, by depriving it of the substance with which it is combined, sets it at liberty, and it then unites with the starch to form the blue compound by which we have an indication of its presence.

Iodine, it has been already mentioned, is always procured from kelp, the product of the combustion of sea-weed, in which it exists as an acid, in union with an alkali. It has been found also in sea water, and in different marine productions, as sponge, coral, and shells of mollusca. It has likewise been detected in small quantity, in different mineral sulphureous waters. It is not put to any particular use, excepting as a cure for scrofulous diseases, in which it is generally administered, in

ternally in the form of tincture, and externally as an ointment.

SELENIUM.

The sulphur procured from the pyrites of Fahlun in Sweden, when employed in the preparation of oil of vitriol, was observed to leave a reddish brown matter, which was supposed to contain arsenic, but Berzelius, during his investigation into its properties, discovered that it contained a substance of a peculiar nature, to which he gave the name of *Selenium*, (An. of Phil. xiii.) It has, however, as yet been obtained in very small quantity, so that we are not much acquainted with its properties.

Selenium differs in its appearance, according to the mode of preparing it. After being fused, it has a deep brown colour, and metallic lustre. When reduced to powder, it is cinnabar red, but during the pulverization it sticks together and becomes grey. Its specific gravity is 4340. Its atomic weight, according to Thomson, is 50. It is a bad conductor of caloric, and of electricity. When heated to 212, it becomes semifluid, and at a few degrees higher is liquefied. If it be allowed to cool slowly, it again becomes of a softish consistence, in which state it can be drawn into threads, and beat out to plates.

When heated in close vessels, it passes off in vapour, rather darker than that of chlorine, and which condenses in the cool part of the apparatus, either in the form of dark-coloured drops, or in *flowers* of a cinnabar colour, according as it is cooled.

When heated in large vessels full of air, a vapour, having the odour of horse-radish, is formed, which is a mixture of two compounds of selenium and oxigen, the one an *oxid*, the other an *acid*. To procure the former, the gaseous matter generated by the heat must be washed with water, by which the latter is absorbed, the oxid being but sparingly soluble in it. Its properties have

not been examined. The other compound will be described with the acids.

Selenium enters into union with hydrogen, and forms a compound called selenuretted hydrogen; but as it is an acid, it will be afterwards described.

Phosphuret of Selenium.

Selenium unites with phosphorus, and forms a phosphuret, which may be procured merely by heating them together, excluded from air. The compound is fusible, having a dark colour, and vitreous aspect. When digested in water, like other phosphurets it is decomposed, the oxigen uniting with the phosphorus, and the hydrogen with the selenium, to form phosphoric acid, and selenuretted hydrogen.

Sulphuret of Selenium.

Selenium unites also with sulphur, merely by fusion but it is difficult to procure the sulphuret pure in this way. It is more easily obtained by passing a stream of sulphuretted hydrogen through a solution of selenic acid by which the hydrogen and oxigen unite to form water and the selenium and sulphur to generate a sulphuret which requires to be washed with a little muriatic acid.

The sulphuret thus formed is fusible at a temperature below that of boiling water, and by the application of a stronger heat is volatilized, but without decomposition, provided air is excluded. If it is present, the sulphur is burned, and the odour of horse-radish is perceptible, from the union of the selenium with oxigen.

Chlorid of Selenium.

When selenium is put into chlorine, its temperature is elevated, there is a gradual absorption of the gas, and a brown liquid is formed, which becomes white and solid as the absorption proceeds. It is chlorid of selenium

When heated in contact with an additional proportion of the latter, a yellowish fluid is formed, which, when thrown into water, deposits selenium, and muriatic and selenic acids are generated, the former by the union of the chlorine and hydrogen, the latter by that of the selenium and oxigen.

The method followed by Berzelius for procuring selenium, consisted in boiling the matter containing it in nitro-muriatic acid, by which it was converted into selenic acid, and then passing sulphuretted hydrogen gas through the solution, to throw it down in the state of sulphuret, from which, by a very complicated process, selenium was procured. A more easy mode of preparing it has been pointed out by Lewenau, (An. of Phil. N. S. viii.) It consists in repeatedly digesting the Fahlun sulphureous matter with nitro-muriatic acid, and distilling nearly to dryness; dissolving the residue, which is selenic acid, in water, and mixing with the solution the salt called *sulphite of ammonia*, which, by its attraction for oxigen, deprives the acid of it, and deposits selenium.

From what has now been said of the properties of selenium, it will be observed, that though Berzelius, when he discovered it, placed it among the metals, it is more nearly allied to sulphur, and hence I have chosen to rank it in the class of bodies acidifiable by oxigen and hydrogen.

FLUORINE.

When sulphuric acid is added to the mineral called *Derbyshire*, or *Fluor Spar*, a gaseous substance is given off, which, so early as the year 1670, was remarked to corrode glass. This elastic fluid, when found to be possessed of acid properties, was considered to be similar in its composition to other acids, that it contained a base in union with oxigen; but all attempts to decompose it proved unsuccessful. After the views of Davy, with respect to the nature of chlorine and muriatic acid, had gained

considerable ground, Ampere conjectured that fluoric, like muriatic acid, might contain a base in union with hydrogen; which idea of its constitution, though at first opposed by Davy, was afterwards supported by him. He published an account of several experiments, (Ph. Tr. 1813,) performed with the view of ascertaining the true nature of the acid, and of discovering its base, in which, however, he did not succeed; but he asserts that the results warrant the conclusion, that the views of Ampere are correct. The reason which induced Davy to adopt this opinion, is the resemblance between the habitudes of fluoric and muriatic acid, particularly the phenomena presented by them, when subjected to galvanism. When muriatic is under its influence, hydrogen is given off at the one wire, and chlorine from the other. When fluoric acid, perfectly free from water, was treated in the same way, the wire, from which there was an evolution of hydrogen in the former instance, also yielded it in this; while the other became covered with a chocolate-coloured powder, which Davy imagined was the base of the acid in union with the metal of the wire.

In other trials, he supposed the base was disengaged, but instantly united with the other body presented to it, or with the materials of the vessel in which the experiment was performed, and hence the difficulty, nay almost the impossibility of obtaining it in its separate state. Davy has, however, no doubt that the acid contains hydrogen in union with a substance, similar in its nature to chlorine and iodine, and to which he has given the name of *Fluorine*.

SECTION IV.

COMPOUND ACIDIFIABLE BODIES.

CYANOGEN.

When describing the properties of carbon, it was mentioned that it enters into union with nitrogen, and forms a gaseous compound, discovered in 1815, by Gay Lussac, (An. de Chim. xcv.) and to which he gave the name of *Cyanogen*, a term derived from κυανος, *cæruleus*, owing to the blue colour of one of its compounds, long used as a paint.

Instead of describing it under Carbon, I have thought proper to bring it in under the class of acidifiable bodies, as sulphur and chlorine, to which, in many respects, it bears a strong resemblance. Thus it unites both with oxigen and hydrogen, and forms acids. It combines also with simple bodies, and forms compounds called *cyanids*, or *cyanurets*, many of which resemble sulphurets and chlorurets in their action with water, the hydrogen uniting with the cyanogen, and the oxigen with the base.

Cyanogen cannot be procured by the direct union of its ingredients, we are obliged therefore to have recourse to decomposition. The substance from which it is usually obtained, is that commonly called *Prussiate of Mercury*, but more properly *cyanuret of mercury*, a compound of mercury and cyanogen. *(See Iron.)*

Cyanogen is a transparent, colourless, elastic fluid, having a strong disagreeable odour. Its specific gravity is 1805, 100 cubic inches weighing 55 gr. When subjected to strong pressure, (Faraday, Ph. Tr. 1823,) it becomes a colourless fluid, which, when exposed to the atmosphere, slowly passes off in the state of gas, producing a great degree of cold. When mixed with water, under increased pressure, there is a gradual action, the mixture becoming dark coloured.

Cyanogen is not affected by exposure to intense heat, provided air is excluded; but if it be present, it takes fire, and burns with a pale red flame. When heated with oxigen it explodes, and for complete combustion it requires twice its volume, by which 2 of carbonic acid and 1 of nitrogen gas are produced. Now, as carbonic acid is known to contain its own bulk of carbon vapour, it is evident that cyanogen must consist of

	Vols.	
Nitrogen, -	1	} condensed into 1;
Carbon gas,	2	}

And hence its composition by weight must be,

Sp. gr. of carbon vapour, $416 \times 2 = 832$

Sp. gr. of nitrogen, 972

and as $972 : 832 :: 17.5 : 15$

$$\text{And } \frac{15}{2} = 7.5$$

So that it is a compound of

1 atom of nitrogen,	17.5
2 atoms of carbon,	15.
and its atomic weight is	32.5

Indeed, its composition by volume shews this; for the atom of each of its ingredients is represented by 2 volumes, and as it contains 1 volume of nitrogen to 2 of carbon, it must have 1 atom to 2. Hence also its specific gravity must be,

$$832 + 972 = 1804.$$

Water absorbs 4½ times its volume of cyanogen, but

at the same time there is a slight decomposition; for the solution reddens vegetable blue, owing to the formation of a little acid, by the cyanogen combining with some of the ingredients of the water.

Cyanogen enters into union with oxigen and with hydrogen, and forms acids possessed of very peculiar properties. It combines also with some of the other simple substances already described, particularly with sulphur and chlorine, and also produces acids, which will be afterwards described.

Cyanogen, it has been already stated, enters into union with other simple bodies, and forms compounds called *cyanids*, or *cyanurets*, which in their properties resemble chlorids and sulphurets, particularly in their action with water, the hydrogen uniting with the cyanogen to form hydro-cyanic acid, and the oxigen with the other substances, to form an oxid, with which the acid combines; so that cyanurets, like chlorurets, sulphurets, &c. are changed to salts by water. These cyanurets will be afterwards described when considering the metals.

XANTHOGEN.

This is another compound acidifiable base, similar in many respects to cyanogen, and which is supposed to contain sulphur and carbon. It was first noticed by M. Zeisse, (Ann. de Chim. et de Phys. xxi.) who gave it the name of *xanthogene*, derived from ξανθος, *yellow*, from the colour of some of its compounds.

When *bi-sulphuret of carbon* is mixed with an alcoholic solution of potassa, the alkali becomes neutralized by an acid, which is a compound of sulphur, carbon, and hydrogen, the two former apparently constituting a compound base, acidified by the hydrogen, and which Zeisse has proposed to call *hydro-xanthic acid*. When to the solution thus formed, a metallic compound is added, there is in general precipitation of a substance, supposed to consist of the metal in union with xanthogen, the hydrogen of the acid having united with the oxigen of the

metal, and thus left the metal and xanthogen to combine. The compounds formed in this way are called *xanthids*, or *xanthurets*, and are of course analogous to sulphurets, chlorurets, &c.; and hence it is that xanthogen must be taken in the same class with sulphur, chlorine, and iodine, because it is not only acidified by hydrogen, but also forms compounds, which are acted on by water, in the same way as those of sulphur, chlorine, &c.

It has been already mentioned, (p. 269.) that chlorocarbonic or phosgene gas, is by some considered an acid; and as it contains chlorine, carbon, and oxigen, if it should really be found to have acid properties, it is not at all improbable that the chlorine and carbon will act as a compound radical, oxigen being the acidifying principle. Should this view of its composition prove correct, we shall have both simple and compound acidifiable bodies, oxigen and hydrogen acting throughout as the acidifying principles.

SECTION V.

ACIDS.

According to the doctrine of Stahl, which so long swayed the minds of chemists, acids were considered simple substances, the inflammables which formed them being supposed to be compounds of them and phlogiston; accordingly, when an inflammable underwent combustion, the phlogiston, it was imagined, was evolved, and the simple base, the acid, was left. Lavoisier was the first who called this opinion in question, and at last, by numerous well-conducted experiments, completely overthrew it, and established another in its stead, founded on the facts deduced from the experiments by which he was enabled to overturn that of Stahl, (p. 177.) Lavoisier held it as a general rule, that acids are composed of a base and oxigen. Thus, he found that when phosphorus was burned in it, an acid was formed, equal in weight to that of the inflammable, and of the elastic fluid consumed. By exposing the compound to the action of other substances, as charcoal, phosphorus was liberated, and another acid generated; hence the conclusion was natural, that the first formed compound contained phosphorus and oxigen. Lavoisier obtained similar results with other acids, and though some of them could not be made

to yield oxigen, yet, reasoning from analogy, he concluded that they were all compounds of a base and this elastic fluid. He therefore considered it as the principle of acidity, and hence its name.

Sir H. Davy was the first who was inclined to call in question the accuracy of the Lavoisierian doctrine, though Gay Lussac had previously thrown out conjectures concerning it. One acid, the muriatic, though exposed to the action of many substances that attract oxigen powerfully, could not be made to yield it. Davy therefore asserted, that it did not contain it, but that it was a compound of hydrogen and another simple body, chlorine. Other substances have since been discovered, which, according to him, generate acids by their union with hydrogen; he therefore concluded, that oxigen is not the only acidifying principle, but that chlorine and iodine may be also reckoned as belonging to the same class.

The doctrine of Davy, though at first received with very great caution, as tending to overturn that of Lavoisier, established apparently on so sure a foundation, is now universally admitted, more particularly, that acids exist in which there is no oxigen. Though Davy considered chlorine and iodine as acidifying principles, yet others maintained that hydrogen is the principle of acidity in those not containing oxigen. From the arrangement I have adopted, it will be perceived, that if we are really to attach a principle of acidity to certain bodies, it should be given to hydrogen, because we find that sulphur, chlorine, and iodine, unite with oxigen, and form one set of acids, and with hydrogen to generate another.

As there are different acids containing the same ingredients, the French chemists, when they constructed their nomenclature, gave them names having different final syllables. Thus, that of the one with the largest proportion of oxigen, had the final syllable in *ic*; that with the smaller in *ous*; as sulphuric, sulphurous; nitric, nitrous. But acids have been lately discovered with smaller and

larger proportions of oxigen than those known when the French nomenclature was constructed, and to distinguish them, the words *hypo* and *hyper* (ὑπο, *under*, ὑπερ, *above*,) are attached; thus, *hypo-sulphurous acid* is one with a less proportion of oxigen than exists in sulphurous acid: *hyper-chloric acid* is one with a larger quantity than there is in chloric acid.

Since the views of Davy have been brought forward, a new nomenclature has been proposed for those acids not containing oxigen. It has been recommended to put the word *hydr* before their names, to shew that hydrogen is one of their component parts. Thus, we speak of the *hydr-acids*, as hydro-chloric, hydr-iodic acid, &c.

The acids have many properties in common. They have a sour taste, and most of them corrode animal and vegetable matter. Their distinguishing feature is reddening vegetable blues, as infusion of purple cabbage, violets, litmus, &c.

In describing the acids, they will be divided into two classes.

1*st*, Acids with oxigen, or *oxi-acids*.

2*d*, Acids with hydrogen, or *hydr-acids*.

ACIDS WITH OXIGEN.

Nitric Acid.

Nitric Acid, in its impure state however, has been long known, and in use in the arts, under the name of *aquafortis*. As generally purchased, it is of a yellowish colour, more or less deep, owing to its containing nitric oxid in solution; and besides, it has in general also a little sulphuric and muriatic acids, derived from the substances used in its preparation. When pure it is transparent and colourless, having a peculiar odour, and a sour taste, and possessing, in a remarkable degree, the characteristic features of acids, being highly corrosive,

and changing vegetable blues to red. Its specific gravity has been differently stated. In general it is about 1550; but this depends greatly on the method followed in preparing it. By the abstraction of caloric it congeals, but the point of congelation varies according to its strength; and what is very remarkable, when it is diluted with a certain quantity of water, the congelation occurs at a higher temperature than when mixed with more or less. Mr Cavendish found that the strong acid became solid at —41.6; but when diluted, so as to make it of sp. gr. about 1300, it congealed at —2, while by adding more water, it again required a much lower temperature; indeed it was nearly the same as that of the strong acid.

The boiling point of the acid also varies according to its strength. And it is also remarkable, that at a certain specific gravity it is much higher than when it is either weaker or stronger, and at that, and that alone, it always passes off in vapour of the same density. Dalton ascertained that the specific gravity alluded to is 1423.7, at which the boiling point is 248. When the acid is stronger or weaker than this, the point of ebullition becomes lower. If weak acid be used, the weakest part first comes over, whereas, when concentrated, the strongest part is first distilled; so that in the former case the residue in the retort becomes stronger, and in the latter it becomes weaker, till in both it arrives at the specific gravity 1423.7, and then the point of ebullition continues steady, and the vapour, when condensed, is of the same strength as that in the retort.

Nitric acid is decomposed by subjecting it to a strong heat, as when its vapour is passed from a retort through an incandescent tube, (*cut, p.* 138;) a gas comes off mixed with red fumes, but which are absorbed by the water of the trough, while the other may be collected. It is a mixture of oxigen and nitrogen with the former in large proportion, for when a taper is introduced it burns with great splendour; and after the combustion is over, and the

vapour formed is allowed to be absorbed by water, the residual gas is nitrogen.

Nitric acid is decomposed also by light. If a phial of it be exposed to sunshine, it gradually acquires a yellowish and ultimately a brownish tinge, which is owing to the formation of a little nitric oxid which is absorbed, at the same time oxigen gas is disengaged. Hence the necessity of keeping the acid excluded from light.

These experiments prove that nitric acid is composed of oxigen and nitrogen; for the discovery of which we are indebted to Cavendish, though Priestley and Lavoisier had been previously led to suppose, from some of their experiments, that this was its constitution. The composition was proved synthetically by Cavendish, by passing electric sparks through atmospheric air, either alone or mixed with oxigen gas. For this purpose wires from the conductors of the machine were passed into a tube, the open end of which was placed in a cup of mercury, over which there was a solution of potassa. After the transmission of the sparks the air was diminished, and the odour of nitric acid was perceptible. A piece of paper dipt in the alkaline solution, deflagrated in the same way as when soaked in a solution of nitre, which is a compound of potassa and nitric acid. Hence Cavendish concluded that the oxigen and nitrogen had been made to enter into union and form the acid, a conclusion confirmed by the analytic experiments just mentioned, its decomposition by heat and light. Though the composition of the acid has been proved, yet very different statements have been given with respect to its proportions. According to an experiment of Cavendish, conducted on a large scale, they were fixed at 72.2 oxigen, 27.8 nitrogen. From the experiments of Henry and others, it has been shewn to be a compound, supposing it quite free from water, of

	Vols.	By weight.
Nitrogen,	2	26
Oxigen,	5	74

and as 26 : 74 :: 17 : 50

so that nitric acid, supposing it free from water, is a compound of

1 atom of nitrogen,	17.5
5 atoms of oxigen,	50.
and its atomic weight is	67.5

Nitric acid unites very easily with water; indeed, so strong is the attraction between them, that it cannot be procured free from it. The quantity of real acid, in acids of different specific gravity, has been variously stated. The latest experiments are those of Thomson, (First Princ. i. 114.) from which he has constructed a table of their composition. *(See Appendix.)*

According to Thomson, acid of specific gravity 1423.7, seems to be the compound in which the parts are held together most powerfully, and is composed, as the table shews, of 1 atom acid, and 4 water. It is that, which, it has been already remarked, boils at 248, the boiling point continuing all the time the same, and giving off vapour, which, when condensed, is also of the same specific gravity.

When nitric acid is mixed with ice, there is a considerable reduction of temperature, but it is necessary to use it diluted, because when of a certain strength, the product congeals easily, and the action ceases. When previously mixed with 1-5th of water, and poured on snow, the temperature falls to —30.

Nitric acid has no action with oxigen or nitrogen.

When exposed to nitric oxid, it absorbs it rapidly, and gradually changes its appearance, first becoming pale, then dark yellow, next brown, and lastly green. The absorption of the oxid by the acid is easily effected. For this purpose, put into a bottle some pieces of copper, and pour on it nitric acid, diluted with two parts of water. Adapt a bent tube, passed through a cork, and allow the action to go on for some time, by which nitric oxid is disengaged; then put the open end of the tube into a phial, containing colourless acid, and as the bubbles of gas are absorbed, the acid will become coloured, the

colour becoming darker as the quantity increases. The properties of the compound formed, will be noticed when describing *Nitrous Acid.*

Nitric acid acts easily with inflammables, the change effected on the acid being the same with all, but the products differ according to the combustible employed.

When exposed to hydrogen at a high temperature, as when its vapour is passed along with it into an incandescent tube, there is an immediate decomposition, the oxigen and hydrogen uniting, and causing explosion, so that the experiment must be performed with great caution.

Phosphorus and sulphur also easily decompose it; in fact the action is so violent, that for the safety of the operator, it is necessary to dilute the acid with about two parts of water. When they are put into a flask and heated, the inflammable gradually acquires oxigen, and is converted into phosphoric or sulphuric acid, while by the loss of oxigen, the other becomes nitric oxid, which flies off in the form of gas.

The action with carbon is similar, but it requires the aid of heat. If a few drops of acid be thrown into a crucible of hot charcoal, beautiful sparks are thrown out, and nitric oxid is disengaged. When the acid is boiled on the charcoal, the same gas is evolved, and it gradually acquires a dark colour. On evaporating the fluid, a clammy substance is left, resembling in some of its properties the astringent principle of vegetables.

Nitric acid is no where in nature found in its pure state. It is generated by the putrefaction of animal and vegetable matter, and it may also be formed by passing electric sparks through air, as in the experiment of Cavendish, but it is not prepared in either of these ways for use. It is always procured by the decomposition of salts, in which it exists as a component part. That usually employed is nitre. *(See Nitre.)*

Nitrous Acid.

When describing the properties of nitric oxid, it was

mentioned, that when mixed with air it unites with oxigen, and forms nitrous acid. If, instead of air, oxigen be employed, the gases also combine, and the same compound is formed. From the experiments of Davy, (Elements,) and of Thomson, (First Pr.) four of the oxid require two of oxigen, by which a brownish gaseous substance is formed, and which continues in this state, provided water is excluded; the moment, however, that it is admitted, there is an absorption, the fluid acquires a greenish colour and a sour taste, and has the power of reddening vegetable blues. The substance thus formed, by the admixture of the gases, is pure nitrous acid, and as in its formation there are required,

oxigen, - - 2 } = 4
oxid 4, containing { oxigen, 2 }
{ nitrogen, 2 = 2

it is evident it must be composed of

	Vols.	Atoms.	
nitrogen,	2	= 1	= 17.5
oxigen,	4	4	= 40.
and its atomic weight will be			57.5

Though liquid nitrous acid may be procured by the absorption of the gas thus formed, it is never prepared in this way for use, being always obtained by the decomposition of nitre by sulphuric acid. *(See Nitre.)*

The fluid commonly purchased as nitrous acid, must not, however, be supposed pure, for besides nitrous, it contains nitric acid, and nitric oxid; and hence the difference in its appearance, being sometimes of a dark brown, and occasionally, though less rarely, green.

Liquid nitrous acid resembles in many respects nitric acid, but in general acts more powerfully on inflammables. When exposed to a moderate heat, it is decomposed, nitric oxid is disengaged, and the residue becomes colourless, and has all the properties of pure nitric acid, and hence the method of procuring that acid. *(See Nitre.)*

When exposed to air, a similar change takes place, by which its colour is destroyed, and nitric acid is formed.

Its action with water is peculiar, the appearance and properties of the product differing according to the proportions. When the dark nitrous acid is mixed with a large quantity of it, the fluid acquires a bluish tinge, but if the acid be in excess, the colour is olive green. These changes depend on a chemical action between the acid and water, for nitric oxid is disengaged, and the product is diluted nitric acid. Supposing, therefore, that the acid is pure, it is evident, that by the addition of the water, one part of it must be made to deprive the other of oxigen, by which the former becomes nitric acid, the latter nitric oxid; and hence it is that we cannot have diluted nitrous acid, the admixture of water always converting it to nitric. The same is the case when it is added to any salifiable base, as an alkali, it is decomposed, nitric oxid gas being evolved, and the nitric acid formed then enters into union with the other to produce a salt. It is this which has made some suppose, that nitrous is not, a distinct acid, but a compound of nitric acid and nitric oxid; an opinion which seems strengthened by the fact, that as yet we have not by any means been able to cause it to enter into union, and form salts, for, though Berzelius has stated that he has succeeded in doing so, yet the later experiments of Gay Lussac warrant the conclusion, that the compounds formed do not contain nitrous acid. (An. de Chim. et de Phys. i. 409.)

According to Davy, the different coloured acids contain different quantities of nitric oxid.

	Acid.	Oxid.	Water.
Pale yellow acid,	90.5	1.2	8.3
Dark orange do.	86.84	5.56	7.6
Dark olive, -	85.4	7.1	7.5
Bluish green, -	84.6	8.	7.4

Nitrous acid, it has been mentioned, acts with great ease on inflammables; indeed, with some the action is so violent, that it is attended with considerable danger. With some of the compound inflammables it is very violent. Thus, if half an ounce of oil of turpentine

be put into a flask, and about as much nitrous acid be poured on it, there is a sudden disengagement of gaseous matter, which instantly takes fire. This experiment succeeds with more certainty, if the acid be slightly heated, and a few drops of oil of vitriol be added to it, just before throwing it on the turpentine. As the disengagement of gas is considerable, it is necessary to use a wide mouthed flask, which should be placed under a chimney, and the acid should be poured in from a glass tied to the end of a long stick.

Nitric and nitrous acid are employed in medicine, externally as an escharotic, internally, when much diluted, in the venereal disease. They are used also in pharmacy, in dyeing, and for etching on iron and copper. To chemists they are of vast importance, being ready solvents of many of the substances on which they have to operate, and hence their use in analysis. The vapour of nitrous acid is now also much employed for purifying apartments, in which those afflicted with contagious diseases have been confined. *(See Nitre.)*

Hypo-Nitrous Acid.

From the experiments of Gay Lussac, (An. de Chim. et de Ph. i. 400.) it appears that there is still another acid of oxigen and nitrogen, and to which the name of *hypo-nitrous acid* has been given.

According to Dalton and Gay Lussac, it may be formed by exposing mixtures of nitric oxid and oxigen, over solutions of potass, by which, when generated, it unites with the alkali. It has not, however, been obtained in its separate state, being always decomposed when a stronger acid is added to its compound, with the view of expelling it.

According to Gay Lussac, hypo-nitrous acid has less oxigen than there is in nitrous acid, being intermediate to it and nitric oxid. Now, as the former contains

1 atom of nitrogen,
4 atoms of oxigen,

and the latter,

1 atom of nitrogen,
2 atoms of oxigen,

hypo-nitrous acid must be composed of

1 atom of nitrogen,	17.5
3 atoms of oxigen,	30.
and its atomic weight will be	47.5

Five compounds of nitrogen and oxigen have now been described, and in these we have a beautiful illustration of combination, in definite proportions.

	Nitr.	Ox.	Atoms.
Protoxid of nitrogen,	100 vol.	50	2.75
Peroxid of nitrogen,	100	100	3.75
Hypo-nitrous acid,	100	150	4.75
Nitrous acid,	100	200	5.75
Nitric acid,	100	250	6.75

Carbonic Acid.

Carbonic Acid, in its pure state, exists in the gaseous form. It was the first elastic fluid discovered different from the air of the atmosphere. Though it must have been often observed during many cases of chemical action, it was not known as a distinct body till the important discovery of Dr Black, who pointed out the difference between it and the atmospheric air, and thus laid the foundation of Pneumatic Chemistry. After he had proved it to be a peculiar substance, its properties were examined by Priestley, (Essays, i. 43.) Bergman, (Opusc.) and Cavendish, (Ph. Tr. 1766.) Dr Black afterwards found that it was generated by the combustion of coal and charcoal, which induced Lavoisier to investigate its properties, by which he was led to the discovery of its composition, (Mem. Paris. 1776,) since which numerous experiments have been performed, with the view of ascertaining the proportions of its ingredients, by Allan and Pepys, Davy, and others, (Ph. Tr. 1807, 1814.) When first discovered, Black gave it the

name of *fixed air*, from its being found in a condensed state in some of the compounds of the alkalies and earths. It was afterwards called *aerial* and *mephitic acid*, the latter applied to it because it proved noxious to animal life. All of these have, however, given way to that of *carbonic acid*, the name used by Lavoisier, shewing that its ingredients are carbon and oxigen.

The experiments by which the proportions of its component parts have been ascertained, have already been detailed at full length, (p. 225.) It is unnecessary, therefore, to recapitulate them; it is sufficient to say, that they are now generally considered to be,

carbon, -	28
oxigen, -	72

that is,

1 atom of carbon,	7.5
2 atoms of oxigen,	20.
and its atomic weight is	27.5

Though carbonic acid gas can be prepared by burning carbon in oxigen, yet it is never procured in this way for use, being always obtained by the decomposition of compounds, into which it enters as a component part. That generally employed is chalk, which is a compound of lime and carbonic acid, and all that is necessary, is to pour on it, placed in a retort, another acid, as muriatic, diluted with about 6 of water, to prevent the action from being too violent. The muriatic acid and lime combine, while the carbonic acid gas is liberated, and may be collected in jars on a water trough.

Carbonic, though a feeble acid, is one of very great importance, not only from its general diffusion through the objects of nature, but also from the important functions it performs in the animal and vegetable creation.

It is a transparent, inodorous, and colourless gas, the specific gravity of which is much greater than that of air. It is now allowed to be 1527, 100 cubic inches weighing 46.5 grains. It is unfit for the support of respiration; even when mixed with a considerable quantity

of air, it can be breathed for a very short time. It also extinguishes combustion, as is shown by the immersion of a candle into a vase of it, and we can thus easily illustrate its great specific gravity. If the cover be removed from the mouth of a jar of it, and a candle immersed some minutes afterwards, the flame is extinguished. Or by inclining a jar of it on a candle, the gas will escape, and put out the flame. It may even be poured from one vessel to another, in the same way as a fluid; for if a jar of it be inclined over another full of air, the carbonic acid will flow into the latter; and that it has, may be shewn by the immersion of a lighted taper.

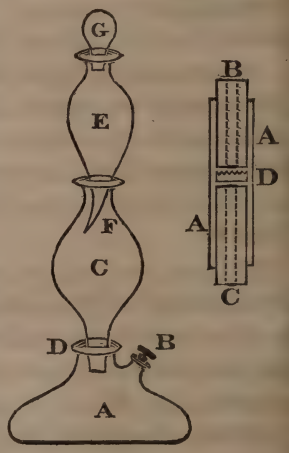
When carbonic acid gas is subjected to great pressure, it lays aside its gaseous form, and becomes a transparent colourless fluid, which is easily distilled by a slight heat, but has not been congealed by the most intense cold to which it has been exposed. (Faraday, Ph. Tr. 1823.)

Exposed to a high temperature, it does not undergo any change. When electric sparks are passed through it, it is decomposed and enlarged, carbonic oxid is formed, and if the transmitting wires be easily united with oxigen, they are at the same time oxidated.

Water absorbs it, though not in great quantity, taking up only about its own bulk; the rapidity of the absorption increasing by agitation, and the proportion imbibed becoming greater, according to the pressure. The absorption of the gas may be shewn by putting a cork into a bottle nearly full of it, and holding the mouth down, shaking it for some time, by which the water absorbs it, air entering through the pores of the cork to supply its place. In this way a saturated solution may be formed, which is transparent and colourless, has an acidulous taste, and sparkles when poured from one vessel to another. By exposure to air, by boiling, by keeping it under an exhausted receiver, and by freezing, the whole of the gas is expelled. The solution has acid properties. It reddens vegetable blues, but the colour is not permanent, unless kept in well-corked vessels; and hence the pre-

sence of this acid, in its uncombined state, is easily distinguished from others. Thus, if litmus infusion be added to carbonic acid water, it becomes red, but on exposure to air, and more particularly by boiling, the original colour returns, the acid having been expelled.

Carbonic acid water is used as a grateful beverage, and as the quantity absorbed may be greatly increased by pressure, this is resorted to in preparing it. The apparatus in common use for procuring it on a small scale, is that recommended by Nooth. A is the vessel containing the mixture of chalk and diluted sulphuric acid, from which the carbonic acid is generated, being introduced at the aperture B. C is the vessel filled with the fluid to be impregnated, having a valve in the tube at D, which allows the escape of the gas upwards, but prevents the water from falling into A. E is a third vessel with a long bent tube, F, fitted to the upper aperture C. The use of this is to receive the water forced up by the pressure of the gas, for when any of it is not absorbed, it presses on the surface of the fluid, and forces it up through F, so that that not imbibed by the water in C, will be taken up by the water in E. G is a heavy stopper to prevent the escape of gas, but when the pressure of this becomes considerable in E, G is raised, so that there is no danger of bursting the apparatus from the increased elasticity.



The valve in D is extremely simple. It consists of an outer tube, A A, into which are inserted two others, B and C, leaving a space between them at D, where there is a small piece of glass, smooth below and rough above, so that, when the gas is generated, the glass is raised, and the rough being brought into contact with the smooth

end of B, there are passages left for it to flow through. When it ceases, the water presses it down, and as there are two smooth sides presented to each other, the fluid is thus prevented from falling through it.

The quantity absorbed in this way is by no means great, but by other contrivances, as by keeping the fluid under considerable pressure, it is much increased, so much so, as to make it effervesce powerfully when the pressure is removed. For this purpose, the fluid which is to absorb it is put into strong vessels, into which the gas, generated in another, is forced, by which a great deal of it is absorbed. From this, when fully saturated, it is drawn off into earthen-ware bottles, and instantly corked, the cork being secured by a wire. In drawing off the fluid, however, a great deal of the gas escapes, unless some means be taken to prevent it. This is done by having a conical cork which will fit the different bottles to be filled. In it there are two apertures, A and B, the former for the admission of the stop-cock from the vessel, the other for the escape of the air from the bottle, and over which there is a cover, kept down by a spring, C. When the bottles are to be filled, the cork is placed on the stop-cock, and then put into the mouth of the bottle; as the water flows in, the air in the bottle is condensed; but when the pressure of this becomes considerable, it raises the valve C, and escapes, so that, the fluid being always under pressure, there is little waste of the carbonic acid.



Carbonic acid is decomposed by carbon at a high temperature, the latter depriving it of part of its oxigen, and reducing it to carbonic oxid, while by the acquisition of oxigen, the carbon itself also becomes oxid, and hence a method of preparing this elastic fluid. For this purpose, a mixture of chalk and diluted sulphuric acid is put into a retort, *(Cut, p.* 138.*)* so that the gas, when generated, may flow through the tube previously filled with charcoal, and brought to a red heat. The gas which comes off, is a mixture of carbonic acid and oxid, a con-

siderable quantity of the acid having escaped decomposition; but it is easily removed, by having the trough filled with lime water, by which carbonate of lime is formed, and the oxid is left pure.

Carbonic acid exists in nature in its pure state. The air of the atmosphere always contains it, but the quantity varies at different times, and in different situations. It amounts sometimes to 1 per cent. while at others it is only 1 in 1000. It was at one time, however, supposed that carbonic acid was not always an ingredient of the atmosphere, particularly in the higher regions, but the experiments of Saussure, Humboldt, and others, have proved that this is not the case, the former having detected it on the summit of Mont Blanc, and the latter in air brought down from a great height by a balloon. That it exists in air, is proved by a very simple experiment. Carbonic acid has a powerful affinity for lime, easily uniting with it, and forming chalk or carbonate of lime; and hence, when shaken with lime-water, it instantly makes it turbid from the formation of carbonate. By exposing, therefore, a plate with lime-water for a very short time, a thin film is formed on its surface, which, when broken, falls to the bottom, and another soon supplies its place. If the fluid be shaken in a bottle half full of it, it soon becomes milky, owing to the formation of a compound of the earth and acid.

Carbonic acid is found in large quantity in pits, in which there is not a free ventilation, and in some caverns also it exists in great abundance, a remarkable instance of which is the *Grotto del Cani* near Naples, which has received its name from a remarkable circumstance noticed by those who first examined it, that it proved fatal to dogs, whereas a man could breathe the air in it with perfect safety; and which is accounted for by the great specific gravity of the gas, which, constantly flowing from chinks near the floor, remains below, and as the entrance to the cave is nearly on a level with the floor, it is not allowed to accumulate, but, on the contrary, rushes out like a stream of water.

From the collection of carbonic acid in mines and pits,

fatal accidents have occurred from people visiting them, when they had not been examined for some time, the air being so much loaded with this aeriform substance, as to prove fatal when breathed. Accidents of this nature are, however, owing to carelessness, for there is an easy method of knowing whether the air in them will prove injurious, which is merely to expose a burning body to it. It is remarkable, however, that some bodies are much sooner acted on than others; thus, a lamp with oil will burn in air in which a candle has been extinguished. In visiting pits and mines, then, in which there is reason to suspect the presence of carbonic acid, a candle or lamp ought to be carried by the individual; and so long as it burns, there is no danger; the moment, however, that it is extinguished, all attempts to proceed farther ought to be abandoned, because the atmosphere, when breathed for a short time, will prove fatal.

Carbonic acid gas is afforded in great abundance by the combustion of substances employed as fuel, as coal, wood, and peat; and that this is the case is proved by holding a jar, open above and below, over a chauffer, and after keeping it there for some time, removing it on a plate, and putting a candle in at the upper aperture, it will be instantly extinguished; or if lime-water be shaken with it, it will become turbid.

As carbonic acid is given off so abundantly during combustion, we ought to be very cautious when using chauffers, or stoves, particularly in apartments in which there is not free ventilation, lest the product escaping into the room, and mixing with the air, prove injurious to those who respire it; which is to be attended to chiefly in bed-rooms, as the gas, when breathed, does not give a person warning of his danger, but, on the contrary, gradually lulls him into a state of insensibility, from which it is difficult to rouse him.

Carbonic acid is also a product of respiration. If a jar be filled with air from the lungs, and which is easily

done by mounting it on a water trough, and inserting into it a bent tube, through which the expired air can be blown, a lighted taper, when introduced, is extinguished; and that this is owing to the presence of carbonic acid, is shewn by shaking the gas with lime water, or, which is still more easily done, by blowing by means of a tube through the water, by which it becomes turbid; but care must be taken in this last instance not to blow too long, because the turbidity will disappear from the solution of the substance, owing to the excess of carbonic acid. *(See Blood.)*

Carbonic acid gas is not put to any use. In solution in water it is employed as a grateful beverage, in which state it is also given for allaying sickness, and stopping vomiting. It is, however, most powerful when administered just as it is set free from some of its compounds, as the alkaline carbonates by the action of another acid. *(See Citric acid.)*

Phosphoric Acid.

Phosphoric acid is found in different states, according to the mode followed in preparing it. When obtained by the rapid combustion of phosphorus, a white flaky matter is formed, which, on exposure to air, acquires moisture, and becomes fluid. This is easily collected by setting fire to a piece of phosphorus, and whelming a bell jar over it, the flakes are deposited on the plate and sides of the jar; and that this has acid properties, is shewn, by putting it into vegetable blue, which becomes red.

When liquid phosphoric acid is exposed to heat, it boils, and the watery part is expelled, and after continuing the ebullition, a dry opake mass is left, which, by increasing the temperature, may be fused, and on cooling assumes a vitreous appearance, and hence its name, *glass of phosphorus*; at one time supposed to be the acid in a state of purity, but now known to contain water,

and from which it cannot be freed by the application of heat.

That phosphoric acid is a compound of phosphorus and oxigen, is proved by setting fire to a piece of phosphorus, and instantly whelming over it the bladdered apparatus, *(Cut, p.* 176.*)* confining the air below by vegetable infusion. As the inflammable is consumed, the water rises to supply the place of the oxigen, and at the same time the colour of the infusion becomes red. On examining it, it is found to contain phosphoric acid.

Lavoisier, from his experiments made with the view of ascertaining the proportion of its ingredients, and which was done by burning phosphorus, found, that 100 united with 154 of oxigen, while Rose made it 114, and Davy 135. The discordance in these results, may have arisen from inaccuracies in the method followed, probably from the whole of the phosphorus not being consumed. By a more accurate mode of analysis, as by the decomposition of its salts, we have arrived at what seems to be the proportion of its ingredients. According to Thomson they are, (First Pr. p. 201.)

phosphorus, 100 or 42.86
oxigen, 133.3 or 57.14
and as 42.86 : 57.14 : : 15 : 20

so that it is composed of

1 atom of phosphorus,	15
1 atom of oxigen, -	20
and its atomic weight is	35

Phosphoric acid easily unites with water. When in the state of white flakes, it combines with it with a hissing noise, but with very little elevation of temperature. When the acid is fused, it also unites with it, but much more slowly. When in this state, it also attracts moisture from the air.

None of the simple inflammables already described have any action with it, excepting charcoal, by which, when exposed to heat, it is decomposed, the oxigen and

carbon uniting to form carbonic acid gas, while the phosphorus, the other ingredient, is liberated, and comes off in vapour, and hence the method always practised in preparing it. For this purpose, the glacial phosphoric acid, after being reduced to powder, is mixed with half its weight of charcoal, and put into a long-necked earthen retort. Having placed it in a sand-bath, and made the mouth to terminate in water, heat is to be applied, by which the gaseous products are given off, composed of carbonic acid mixed with phosphuretted hydrogen; and at the same time the phosphorus rising in vapour is condensed in the cold water, so that the process must be continued as long as there is any phosphorus coming over; great care must, however, be taken to keep the mouth of the retort all the time under water, and to prevent the neck becoming stopped from the consolidation of the phosphorus, and which is known by the diminution of the bubbles of gas; a hot wire must be occasionally introduced to melt it, the mouth being still kept under the fluid. As earthen retorts are extremely porous, unless glazed, it is necessary to immerse them into a thin paste made of a mixture of borax and lime, which is fused by the heat, and forms a dense coating, that prevents the exudation of the phosphorus.

The phosphorus obtained in this way is not pure. It is dark coloured and opake, owing apparently to its containing a little carbon, but from which it is easily freed, by squeezing it through leather, keeping it under warm water, which will melt it, and at the same time prevent its combustion.

This decomposition is an analytic proof of the composition of the acid, that it contains phosphorus and oxigen, the latter of which has combined with the carbon.

Phosphoric acid may be obtained, as has been already mentioned, by the rapid combustion of phosphorus. It may also be procured by boiling diluted nitric acid on it, by which the phosphorus gradually acquires oxigen, becoming phosphoric acid, while nitric oxid is at the same time disengaged; and after the whole of the phosphorus

has disappeared, the fluid must be boiled, till it ceases to give off acid vapour, and which is known by that coming off not reddening litmus paper.

Another method of preparing phosphoric acid, is by the decomposition of burnt bones, which contain it in union with lime. *(See Phosphate of Lime.)*

Phosphorous Acid.

Phosphorus unites with a smaller proportion of oxigen, and forms phosphorous acid, which it was at one time supposed was generated when it was burned slowly in air. The product of the action is not, however, pure phosphorous acid, but a mixture of it and phosphoric acid.

Sir H. Davy has given a method by which phosphorous acid, of uniform composition, may be formed. A quantity of phosphorus is put into a tube, so as to occupy a few inches at the lower end of it, and over this is placed some corrosive sublimate in powder, which is a compound of mercury and chlorine. Heat is then applied, so as to melt the phosphorus, and drive it in vapour over the other, by which the chlorine and it unite, and form a chlorid; and if the opposite end of the tube be kept in water, the moment that the chlorid comes in contact with it, there is a double decomposition, the hydrogen and the chlorine uniting to form muriatic acid, and the phosphorus and oxigen, phosphorous acid. From this the former can be expelled by heat, and the latter is thus obtained pure. When evaporated to dryness, a soft crystalline mass is left, having a sour taste, and reddening vegetable blues.

When heated, excluded from air, a gaseous fluid is given off, which is hydro-phosphoric gas, and phosphoric acid remains in the apparatus. These are formed by the decomposition of the water existing in the acid, the oxigen having united with part of the phosphorous acid, to form the latter, and the hydrogen with some of the phosphorus, to produce the former, and hence the method generally followed in procuring it, (p. 244.)

According to Gay Lussac and Berzelius, phosphorous acid is composed of 100 phosphorus, and about 76 oxigen, whereas, according to Davy, the ingredients are 100 to 67.5. This last seems to be the more correct, not only because it nearly agrees with the result of the experiments of Thomson, but also because it would make the oxigen to be one half of that in phosphoric acid, and consequently in accordance with the atomic doctrine. Phosphoric acid, it has been stated, is composed of 100 phosphorus, and 133.3 oxigen, so that, if we suppose the oxigen in the phosphorous to be the half, the proportion will be

phosphorus, 100
oxigen, 66.6
and as 100 : 66.6 :: 15 : 10

so that it contains

1 atom of phosphorus, 15
1 atom of oxigen, 10
—
and its atomic weight is 25

The two acid compounds already described, are those, the composition of which has been ascertained; others have, however, been supposed to exist. Thus, Dulong conceived that that generated by the slow combustion of phosphorus, was a peculiar acid, to which he gave the name of *phosphatic*, (An. de Chim. et de Ph. ii. 141.) but the existence of this has by others been called in question; indeed, from the experiments of Davy, it seems proved, that the product is a mixture of phosphoric and phosphorous acids, always in the same proportion.

There is still, however, according to some, another acid, to which they have given the name of *hypo-phosphorous*, but even this has not yet been proved to be a distinct acid, having phosphorus and oxigen as its ingredients, so that we are to consider phosphoric and phosphorous as the only established compounds of these substances.

The acids of phosphorus are not put to any use, ex-

cept for making them yield phosphorus, as already described.

Boracic Acid.

Boracic acid is obtained in the form of white shining scales, having a greasy feel like that of spermaceti. They have a sour taste, but are destitute of smell. Their specific gravity is 1479. When exposed to heat, they at first swell, owing to the water of crystallization, and then fuse, becoming a transparent vitreous-looking body, but which on cooling is opake. If the heat be continued, there is no evaporation, unless a little water is present; and hence it is, that when the temperature is suddenly raised, some of the acid is carried off with the watery vapour. The fused mass is the acid free from water.

Boracic acid is soluble in water, but very sparingly so, according to Davy, requiring about 50 parts at a boiling heat. The solution is transparent and colourless, and reddens vegetable blues.

It is also soluble in alcohol, which, when it has dissolved it, burns with a green flame.

Boracic acid is not acted on by any of the simple bodies or acids already described.

Till the year 1807, the composition of boracic acid was not known. Like other acids, it was supposed to contain a base in union with oxigen, but this was mere conjecture, till Davy succeeded in decomposing it, and proved it to be a compound of oxigen and boron, which he did by subjecting it to galvanism, and also by exposing it to a strong heat along with a substance, *(Potassium,)* which has a powerful attraction for oxigen. Gay Lussac and Thenard have arrived also at the same conclusion. The composition of the acid has not yet been accurately ascertained. Davy supposes it to contain about 2-3ds, while the French chemists say that it has only 1-3d of its weight of oxigen. Thomson, from reasoning founded on the atomic doctrine, considers its composition to be

boron,	10
oxigen,	20
its atomic weight being	30

But he admits that the experiments by which this has been ascertained, are by no means satisfactory.

Boracic acid is found native, though sparingly so, in some springs in Tuscany, and it enters into the composition of minerals; but the substance in which it is presented in greatest abundance, is *borax* or *tincal* of commerce, brought from Thibet, and from which it is always procured, for as it is a compound of the acid and the alkali soda, all that is necessary is to decompose it by a stronger acid. *(See Borax.)*

The acid is not put to any particular use.

Arsenous Acid.

It has been already mentioned, (p. 247.) that when arsenic is heated in air, it is inflamed, and a white matter is formed, which has been long used under the name of arsenic. It is now known to be an acid, and has been called *arsenous acid.* Though it can be procured by the direct union of its ingredients, it is never prepared in this way for use, being formed in those processes in which the native sulphurets are exposed to heat. In the preparation, also, of some of the metals from their ores, the arsenic they contain is given off in the form of arsenous acid.

It is commonly purchased in white cakes, under the name of arsenic or white arsenic, and frequently also in powder. It has an acrid taste, and is one of the most virulent poisons with which we are acquainted.

Arsenous acid is not so volatile as arsenic, though its vaporific point is not much higher, being only 383.

Different statements have been given of the action of water on the acid. According to Klaproth, 1000 at the natural temperature take up only about $2\frac{1}{2}$, but when boiling, about 77. Fischer, on the contrary, asserts tha

arsenous acid is insoluble, but when put into water, one part of it takes oxigen from the other, to form arsenic acid, which is soluble. The solution is transparent and colourless, and reddens vegetable blues.

The results of the experiments performed, with the view of finding its composition, vary considerably. They are, according to

	Proust.	Berzelius.	Thomson.
Ar.	100	100	100
Ox.	32.9	31.8	42.1

Supposing the last to be correct,

as 100 : 42.1 : : 47.5 : 20

so that, according to this, it is composed of

1 atom of arsenic,	47.5
2 atoms of oxigen,	20.
and its atomic weight is	67.5

When arsenous acid is exposed to heat with charcoal, there is a decomposition, carbonic acid gas is disengaged, and arsenic is sublimed, and hence the method of procuring it. All that is necessary, is to introduce the mixture of acid and charcoal into a retort, having a receiver adapted to it, and apply heat; the vapour comes off, and is condensed in the receiver. As, however, the acid is very volatile, it is better to mix a little of the alkali potassa with the ingredients, by which it is prevented from escaping in vapour, before the temperature reaches that necessary for its decomposition. Instead of charcoal and potass, the substance called *black flux* is used, and which is prepared by burning cream of tartar. It is a compound of potassa with carbonic acid mixed with charcoal. *(See Supertartrate of Potash.)*

Arsenic Acid.

Arsenic acid may be prepared by digesting arsenous acid in nitric acid, but a better method is to employ a mixture of nitric and muriatic. For this purpose three

ounces of arsenous acid are boiled with seven of muriatic acid, till the whole is dissolved, after which five of nitric acid are added, and the heat continued, till a white saline mass is obtained, which is the pure acid. In the first part of this process, it is supposed that the muriatic merely dissolves the arsenous acid, and thus renders it more easily acted on by the nitric, which communicates oxigen to it, and converts it into arsenic acid, nitric oxid being evolved.

Arsenic acid is soluble in water, forming a transparent colourless solution, which reddens vegetable blues. It is not volatilized by heat, in this respect differing from the other; but if the temperature is very high, it is decomposed, part of the oxigen is expelled, and arsenous acid is formed.

Arsenic acid, according to Thomson, is composed of

arsenic,	100.
oxigen,	63.1

and as 100 : 63.1 : : 47.5 : 30,

so that it contains

1 atom of arsenic,	47.5
3 atoms of oxigen,	30.
and its atomic weight will be	77.5.

If the statement now given of the composition of the compounds of arsenic is correct, there must be another with a smaller quantity of oxigen, so as to make that in arsenic acid, a multiple proportion. This has not, however, yet been discovered.

Sulphuric Acid.

It has not been ascertained at what time this acid was discovered. It is mentioned by Basil Valentine, who wrote in the beginning of the 15th century, but it was probably known before that. It was formerly obtained by the decomposition of a salt, containing it in union with iron, called *green vitriol*, and hence its name in commerce, *oil of vitriol*, being of an oily consistence.

This method is not now practised here.—It is usually obtained by the combustion of sulphur mixed with nitre. *(See Nitre.)*

Sulphuric acid, as usually obtained, is a transparent colourless fluid, of an oily consistence, having a very sour taste, highly corrosive, and reddening vegetable blues. When as pure as usually prepared, it is of specific gravity 1847, but even in this state it contains a considerable quantity of water, and from which it cannot be freed by heat. According to Dalton and others, it has at least 19 per cent.

And as 19 : 81 : : 11.25 : 49.

Now it will be shewn immediately that 50 is the atomic weight of the acid, so that we may consider oil of vitriol as composed of

1 atom of acid,	11.25
1 atom of water,	50.

And if so, its composition by weight must be,

sulphuric acid,	81.67
water,	18.36

When of greater sp. gr. than 1847, it is not pure, being contaminated with a little lead, derived from its action on the walls of the chamber in which it is prepared.

By the abstraction of caloric it freezes; but the congealing point varies according to its strength. When strong, it becomes solid at about —15, and puts on a crystalline appearance, at the same time suffering a slight diminution in volume.

By the application of heat it is made to boil, but the point of ebullition depends also on its strength. When concentrated, it boils, according to Dalton, at 620, and then passes off in vapour, which is very offensive, and hence the necessity of being cautious in the performance of the experiment. It ought to be done in a well-ventilated room, to allow the vapour to escape, and the heat should be applied gradually, so as to get the whole of the fluid properly warmed, otherwise, if vapour is formed before this is done, it is condensed as it rises through the super-

incumbent fluid, and the agitation produced is apt to break the vessel.

As sulphuric acid can thus be driven off in vapour, it affords an easy means of purifying it, when we wish it for delicate experiments. All that is necessary, is to place it in a large retort, so that it does not occupy much of the bulb, and apply heat cautiously. When the acid begins to boil, the temperature must be so regulated, as to continue the ebullition slowly, and by adapting a receiver kept cool by ice, the vapour will be condensed; but as the first part that comes off is weak, it must be rejected, so that when about 1-6th has passed over, the receiver may be changed, and the distillation continued till a sufficient quantity is obtained.

Sulphuric acid has a strong attraction for water. If exposed to the air, or to any gas loaded with moisture, it unites with the vapour, and increases in weight, so much so as actually to gain 1-3d in the course of 24 hours.

The union of the acid and water is attended with remarkable phenomena. There is a considerable condensation, and consequent rise of temperature, the amount of which depends on the proportions employed; and that there is so, may be shewn, by using a long tube as a measure. First fill it with acid, and having emptied it into a glass, fill it with water, and pour this on the other; but before doing so, wrap some tow with a chip of phosphorus around the glass. The moment that the fluids are mixed, the phosphorus is inflamed, shewing the evolution of heat; and after allowing the mixture to cool, again measure it, and it will be found that there is considerably less than 2 volumes. Gadolin found, that 2 of acid and 1 of water had their temperature raised about 200; equal parts produced an elevation of 175, and 2 of water and 1 of acid, only 108. The greatest rise is occasioned by using them, according to Ure, in the proportion by weight of 73 of acid to 27 of water.

If the acid employed in this experiment is pure, the mixture continues transparent, but if that of commerce be used it becomes opake, owing to the deposition of the compound of lead, which it always contains. This af-

fords another mode of purifying the acid, for after mixing it with water, the metallic compound may be allowed to fall to the bottom, and the clear fluid may be drawn off. If required concentrated, all that is necessary is to boil it, till it becomes of the requisite density.

For the proportion of real acid in acids of different specific gravity, *see Appendix.*

When the acid is poured on ice, there is a change of temperature, but it differs according to the proportions. If little acid be employed, there is a generation of cold, whereas, when the ice is in smallest quantity, heat is disengaged, (see p. 101.)

The abstraction of caloric from diluted acid is attended with peculiar phenomena. Mr M'Nab found (Ph. Tr. lxxxi.) that the concentrated acid was frozen at —15, while that diluted with rather more than half its weight of water, did not congeal till it reached —36. On the contrary, however, when mixed with about 1-4th, or so as to make the specific gravity 1780, and in which state it contains exactly 1 atom of acid and 2 of water, it is frozen by plunging it into snow ; and having got it solid, it continues in that state though the temperature is raised to 45. If more or less water is used, the heat necessary for the congelation becomes lower.

When the acid is mixed with snow, till there is no farther evolution of caloric, and is then reduced to —60, and in this state added to snow at the same temperature, the mixture sinks to —91, the greatest cold yet accurately measured, (see p. 99.)

By the application of heat to diluted acid, the water is driven off ; it is thus got of sp. gr. 1847, still containing, as already mentioned, nearly 19 per cent. It is from this circumstance, the impossibility of freeing the acid entirely of its water, that it has been proposed to call the common acid, or oil of vitriol, *hydro-sulphuric*, a term, however, not altogether correct, as *hydro* is attached to the names of those acids containing hydrogen. It ought to be *hydrated* or *hydrous sulphuric* acid, the terms given to those bodies containing water.

Though sulphuric acid cannot be freed of its water by

the application of heat, or indeed by any other means, *anhydrous* acid may be obtained by the distillation of green vitriol, which is a compound of it and oxid of iron. For this purpose, after being deprived of its water of crystallization, it is put into a retort, to which a receiver is adapted, and kept cold. On applying a strong heat, the acid is expelled, and is condensed in the receiver, and by a second distillation, part is distilled over, and is obtained in a crystalline form, in which state it is *entirely free from water.*

When the anhydrous acid thus prepared is exposed to the air, part flies off in vapour, and the remainder becomes liquid, from its attracting moisture. It is liquefied at 66, but to preserve it fluid it must be kept at 77, otherwise small tufts of crystals are formed. It chars vegetable matter the instant it touches it. When thrown into water it combines with it rapidly, emitting a hissing noise as when a hot iron is plunged in it.

Sulphuric acid, though considered by Stahl a simple substance, is now known to be a compound of sulphur and oxigen; and that it is so, is proved synthetically by burning sulphur in the bladdered apparatus with oxigen, over cabbage infusion, which, as it rises to supply the vacuum, *is reddened*, showing the production of acid; and that this is sulphuric is proved by submitting it to chemical tests, by which this acid is detected.

It is difficult to ascertain the proportion of the ingredients by the combustion, owing to the generation of another compound of sulphur and oxigen; and different statements have been given of its composition. The ingredients are, according to

	Lavoisier.	Berthollet.	Thenard.
sulphur, -	69	61.5	55.6
oxigen, -	31	38.5	44.4
	100	100	100

The discordance in the results of these experiments was caused by the inaccuracy of the methods employed, the compounds of sulphuric acid formed having been de-

composed by means of a substance, the composition of which was not accurately known; but since the proportions of the ingredients of this have been discovered, those of sulphuric acid have also been ascertained. They have been found to be very nearly 40 to 60, and if we make allowance for inaccuracies in experiment, we may consider this as its composition.

And as 40 : 60 : : 20 : 30;

so that we may consider it a compound of

1 atom of sulphur, - - -	20
3 atoms of oxigen, - - -	30
and its atomic weight is -	50

This is, of course, the composition of the real acid, or that which enters into union with bases and forms salts.

It has been already mentioned, that the acid of commerce, and which is of specific gravity 1847, is a compound of 1 atom real acid, and one atom water. Hence its atomic weight will be 61.25, (50 + 11.25 = 61.25.)

Sulphuric acid is decomposed by many of the simple bodies already described, as by phosphorus, carbon, and sulphur, the whole of them taking oxigen from it, and reducing it to a lower state of oxidation, by which sulphurous acid is formed, a compound with a smaller proportion of oxigen. When any piece of vegetable matter, and which contains carbon, as wood, straw, cork, or sugar, is thrown into the acid, it gradually, even at a natural heat, acquires a dark tinge, owing to the solution of a part of the carbon. Hence the cause of the dark colour of the acid frequently met with in commerce, some vegetable matter having accidentally fallen into it. From this, however, it may be freed merely by boiling, by which the carbon acquires oxigen, and is dissipated in the form of carbonic acid, while at the same time, a little sulphurous acid, another compound of sulphur and oxigen, but with less of the latter, is also evolved.

When sulphur is boiled in sulphuric acid there is a similar decomposition, it unites with part of its oxigen

to form sulphurous acid, while the other, by being deprived of this, is also brought down to the same state.

Sulphuric acid is occasionally found pure. In some volcanic countries it issues in vapour from chinks in the ground, and being absorbed by the adjacent waters, gives the appearance of lakes of it. In its combined state, it is a very abundant production, united chiefly to the earths and metals.

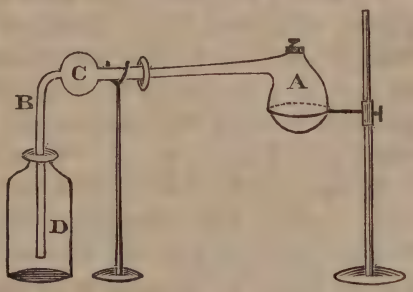
There is, perhaps, no substance more useful, or more abundantly employed in the arts and manufactures. It is used in medicine, when largely diluted, as a refrigerant, and is very efficacious in stopping profuse perspiration. It is used in pharmacy in the preparation of many medicines. It is employed by bleachers for souring the cloth; by dyers, for dissolving their indigo; by calico printers, for forming the *sours* in which they soak the cloth, previously to its immersion in the dye-stuff; by brass-founders, button-makers, gilders, and japanners, for cleaning the surface of the metals with which they work; and by hatters, tanners, paper-makers, and many others. It is used also in the preparation of nitrous and muriatic acid.

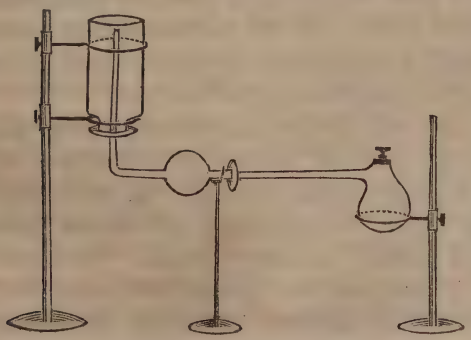
Sulphurous Acid.

It has been already mentioned, that when sulphur and sulphuric acid are boiled together, sulphurous acid is formed. Though it can be procured in this way, yet the method is seldom followed, because, owing to the high temperature necessary for the decomposition, a good deal of the sulphuric acid comes off in vapour, and contaminates the other. An easier mode of preparing it, is to deprive the acid of its oxigen by means of a metal, as mercury. For this purpose, having put about 1-8th part of an ounce by weight of mercury into a retort, pour on it an ounce of oil of vitriol, and apply heat so as just to keep up the disengagement of gas. The sulphurous acid comes off, and must be collected over mercury, because it is easily acted on by water. In this

instance, the mercury taking a part of the oxigen from the sulphuric acid, reduces it to the state of sulphurous acid, while the oxid of mercury formed is left in union with the remainder of the acid not decomposed. This acid gas may also be prepared by heating some of the metallic oxids, as red oxid of mercury, or oxid of manganese, with sulphur, *(see these.)*

As the use of a mercurial trough is both inconvenient and expensive, there is an easy mode of preparing gases without having recourse to any trough, merely by the displacement of the air of the vessels in which they are to be collected, provided they are not very noxious. For this purpose the retort, A, containing the mixture, has a bent tube, B, adapted to it, with a bulb at C, to collect any moisture that may be condensed. The tube passed through a cork which fits the mouth of the bottle D, is made to terminate near the bottom. If the gas is heavier than air, the mouth of the bottle must be kept up, as represented in the cut, so that, as it escapes at the bottom, it may gradually push out the lighter air above it. If lighter, the apparatus must be adjusted as in the lower figure, with the mouth of the





bottle below, so that it may force down the heavier air. In this way, by carrying on the process for some time, though a good deal of the gas escapes, yet the receivers may be very nearly filled with it, and it is sufficiently pure for many purposes, as for merely shewing the general properties.

Sulphurous acid is a transparent colourless gas, possessing the usual mechanical properties of aeriform fluids. It has an acid taste and an offensive odour, being extremely irritating to the nostrils and lungs. It is unfit for the support of respiration and combustion. Its specific gravity, as given by different authors, is, according to Lavoisier, 2010; Dalton, 2300; Thomson, 2222; which last is considered the most correct.

By strong pressure it has been condensed into a transparent colourless fluid, as limpid as water, and which, though cooled to 0, does not freeze; but on exposure to air part of it flies off in the form of gas, and by the evaporation reduces the temperature of the remainder so much as to keep it liquid. When a small piece of ice is thrown into it, it instantly makes it boil, owing to the rapid action, and consequent disengagement of heat. Sulphurous acid gas may also be made to lay aside its gaseous form, by exposing it at the same time to cold, and to substances that will deprive it of any foreign moisture. Thus, if when generated from any of the mixtures mentioned, the bulb, C, of the apparatus represented in last page, be filled with the substance called muriate of lime, which has a powerful attraction for water, and the bottle, D, be surrounded by a mixture of ice and salt, a transparent colourless liquid is obtained, and which is *anhydrous sulphurous acid.*

When the acid thus prepared is exposed to the air, under the usual pressure, it flies off in the form of gas, generating a great degree of cold. If, for instance, it is poured on water, it evaporates and reduces its temperature, so as actually to make it freeze. Or if the bulb of a mercurial thermometer covered with muslin be immersed in it, and then whirled in the air, the mercury itself

is frozen. Even some of the gases may be condensed with it, merely by surrounding the tube containing them with cotton, the cold produced by the evaporation being sufficient to cause them to become fluid.

Water absorbs sulphurous acid gas. If a little be introduced into a jar of it standing over mercury, there is an absorption, the mercury with the water on its surface rising and filling the jar. Or if the mouth of the retort from which the gas is issuing, be placed in water, there is no escape of it, the whole being instantly absorbed, so that in this way a saturated solution can be prepared. According to Dalton, water takes up 22, according to Thomson 33, and according to Saussure 43 times its volume of the gas. The solution is transparent and colourless, of specific gravity 1050. When exposed to cold, so as to freeze it, the gas is not liberated. On exposure to air, it is gradually converted to sulphuric acid, owing to the absorption of oxigen.

Though the gas is thus easily absorbed by water, it is remarkable that the fluid has not the distinguishing character of an acid, that of reddening vegetable blues; on the contrary, it banishes them, as when it is added to cabbage infusion. The colour is not, however, *destroyed*, for if any other acid be added, as sulphuric acid, it is recalled, and then becomes red.

The action between sulphurous and nitrous acid gases is important, provided water is present. When mixed in a jar over mercury, and quite dry, there is no action, but the moment a little water is admitted, the colour of the nitrous acid disappears, the sulphurous acid acquires oxigen from it, and sulphuric acid and nitric oxid are generated, the former of which is absorbed by the fluid, while the latter remains gaseous; (nitrous acid for this experiment is easily prepared by putting nitric oxid and oxigen into the jar.) On the introduction of air or oxigen, more nitrous acid may be produced, and which, on the admission of more sulphurous acid, will give off oxigen to it, to convert it into sulphuric acid; so that by a small quantity of nitric oxid, any quantity of sulphurous may

be converted to sulphuric acid, provided air and water are also present. It is in this way it is supposed to act during the preparation of oil of vitriol. *(See Nitre.)*

Sulphurous acid gas is decomposed by exposing it to substances having a powerful attraction for oxigen, as when it is passed through an incandescent tube with hydrogen, or over red-hot charcoal, the hydrogen or carbon forming water, or carbonic acid, and causing a deposition of sulphur. When iodine is put into its solution, the water is decomposed, and sulphuric acid, and a compound of iodine and hydrogen, are formed.

All of these experiments prove, that it is composed of sulphur and oxigen, and the statements of different chemists very nearly agree with respect to their proportions. They are, according to

	Berzelius.	Gay Lussac.	Thomson.
Sulphur,	50.03	51.3	53
Oxigen,	49.97	48.7	47
	100	100	100

The slight discordance in these results is owing to the formation of a little sulphuric acid during the experiments, which were conducted by burning the sulphur in oxigen.

Davy and Gay Lussac assert, that when oxigen unites with sulphur to form the acid gas, there is no change in volume. If so, we have an easy method of determining the proportions, we have merely to deduct the sp. gr. of oxigen from that of the gas, and the remainder is the weight of the sulphur.

$$2222 - 1111 = 1111.$$

So that they are in equal weights, and with which Berzelius's statement very nearly agrees; consequently, 20 being the atom of sulphur, and 10 that of oxigen, sulphurous acid must contain

1 atom of sulphur,	20
2 atoms of oxigen,	20
and its atomic weight will be	40

Sulphurous acid gas is absorbed by sulphuric acid, and gives it a brownish tinge, but from which it can be freed by boiling. The fluid emits fumes on exposure to air, and is congealed by a slight reduction of temperature.

The only use to which sulphurous acid is applied, is in bleaching, particularly worsted stuffs and straw. For this purpose the goods, after being wetted, are hung up in rooms or boxes, in which the sulphur is burned in small dishes; the fumes are absorbed by the moisture, and act on the colouring matter, gradually destroying it. The action of the fumes of sulphur is beautifully illustrated, by suspending a rose in the upper part of a glass jar, open at each end, and placing it over a dish with burning sulphur, leaving an opening below, for the admission of air. After being left in for some time, the colour gradually disappears. The same may be done also with many other flowers, or with a leaf of red cabbage. Though the colour is thus banished, it is not destroyed; it may be recalled by the action of a stronger acid. If the rose be placed into much diluted sulphuric acid, it gradually becomes red again; and it is also remarkable that the vitality of the flower is not injured; so that the blanching may be done only on one or a few of those on a plant, which afterwards continues quite healthy.

Hypo-Sulphurous and Hypo-Sulphuric Acid.

Two other acids of sulphur and oxigen have been described, the one by Herschell, the other by Gay Lussac and Welter.

When sulphur is boiled with alkaline solutions, compounds are formed, which contain the alkali in union with an acid composed of sulphur and hydrogen, the latter derived from the decomposition of the water. When these are exposed to air oxigen is absorbed, which uniting with the sulphur, converts it into another acid, now called *hypo-sulphurous*, *(See Sulphuretted Hydro-Sulphuret of Potass.)* This acid has not, however, been procured in its separate state, but from the expe-

riments of Mr Herschell, (Ed. Ph. Journ. i. 8,) there is every reason to believe, not only that it is a distinct acid, but also that its composition is

sulphur,	100
oxigen,	50

If so, it contains

1 atom of sulphur,	20
1 atom of oxigen,	10
and its atomic weight will be	30

Hence also the origin of the name *hypo-sulphurous*, being an acid with less oxigen than exists in sulphurous, (ὑπο, under.)

The other acid, which has been called *hypo-sulphuric*, is, according to Gay Lussac, (An. de Chim. et de Phys. x.) a compound of

sulphur,	100
oxigen,	125

It is doubtful, however, if this is really a distinct acid, more particularly as in its composition it does not accord with the atomic doctrine, 125 not being a multiple of 50, which is the oxigen in that with the smallest proportion. Others, who allow the existence of an acid in these proportions, are inclined to consider it as composed of an atom of sulphurous and an atom of sulphuric acid, together, making a compound acid; if so, its composition will be

	Sulph.	Ox.
1 atom sulphurous acid =	20	20
1 atom sulphuric acid =	20	30
And the compound atom will contain	40	50

And as 40 : 50 : : 100 : 125,
the proportions yielded by its analysis.

Chloric Acid.

This is the acid that exists in the salt which, it has been already mentioned, is employed in the preparation of the two oxids of chlorine, and which has been long

known by the name of the *hyper-oximuriate of potass.* Many attempts had been made to procure the acid in its separate state, but without success, till Gay Lussac, in 1814, (An. de. Chim. xci.) pointed out a method of doing so, from a salt containing it in union with the earth baryta. For this purpose, to a solution of the chlorate of baryta, (*see the Chlorate,*) add sulphuric acid as long as there is any precipitation, by which the baryta is precipitated with it, and the chloric acid is left in solution, and may be concentrated by evaporation.

As thus prepared, it is a transparent colourless fluid of an oily consistence, having an acid taste, and reddening vegetable blues. By the application of strong heat, part of it is volatilized, part decomposed, and resolved into its constituents, oxigen and chlorine.

The proportions of its ingredients have been discovered, by decomposing some of its salts, as that used in the preparation of the oxid, and which is done merely by the application of heat, *(see Chlorate of Potass,)* by which oxigen gas is disengaged, and the chlorine is left in union with the metallic base of the potass; so that, by collecting the former, and weighing the latter produced by the decomposition of a certain weight of the salt, the proportions are found. Thus, 100 of the dry salt yield 38.88 of oxigen, and leave in the retort 61.12 of the compound of chlorine and potassium, which consists of 28.92 chlorine, and 32.18 of potassium. Now, 32.18 require 6.57 of oxigen to convert them to potass, in which state they existed in the salt, and deducting this from 38.88, leaves 32.31, which must have been in union with the 28.92 chlorine; and

as 28.92 : 32.31 : : 45 : 50;

so that we may consider it composed of

1 atom of chlorine,	45
5 atoms of oxigen,	50
and its atomic weight	95

And as an atom of oxigen is represented by 1 volume, and that of chlorine by 2, chloric acid must consist of

	Vols.
chlorine,	2
oxigen,	5

Per-Chloric Acid.

Count Van Stadion of Vienna has given an account of another acid of chlorine and oxigen, and to which the name of per-chloric has been given. When the deutoxid of chlorine is prepared from the mixture of sulphuric acid and chlorate of potass, a saline matter is left in the apparatus, which contains potass, partly in union with this acid, and which may be separated by sulphuric acid. *(See Chlorate of Potass.)*

According to Stadion, the salt containing it in union with potass, is decomposed by heat, by which oxigen is given off, and the chlorine is left in union with the metallic base of the alkali; so that, by collecting the oxigen, and weighing the residuum from a certain weight, he has fixed the proportions at

chlorine,	39
oxigen,	61
	100

and as 39 : 61 : : 45 : 70;

so that, if the experiment is correct, it is a compound of

1 atom of chlorine,	45
7 atoms of oxigen,	70
its atomic weight being	115

	Vols.
that is, of chlorine,	2
oxigen,	7

With the properties of this acid we are not at all acquainted.

Iodic Acid.

Iodic acid was discovered by Davy, (Ph. Tr. 1815.) It cannot be procured by the direct union of its ingredients, but it may be formed by exposing iodine to the action of substances containing oxigen, for which purpose euchlorine is employed. When the mouth of the retort from which this is issuing, when generated in the usual way, *(see Chlorate of Potassa,)* is placed in a bottle containing iodine, two new compounds are formed, one containing iodine and chlorine, the other iodine and oxigen. By the application of heat, the former is driven off, and the latter is left. It is iodic acid.

Iodic acid, as thus procured, is a white semi-transparent substance, having a very acid taste, first reddening, and then destroying, vegetable blues. When subjected to heat, it is decomposed, and resolved into its component parts, by which we have a method of finding the proportions of its ingredients. According to Davy, 100 grains give out 23.6 of oxigen; so that the remainder, 76.4, must have been iodine, thus making the proportions,

iodine,	76.4
oxigen,	23.6

Gay Lussac, by decomposing it in the same way, has fixed them at 75.76, and 24.24;

and as 75.76 : 24.24 : : 155 : 48;

so that, making allowance for error in experimenting, it is probably a compound of

1 atom of iodine,	155
5 atoms of oxigen,	50
its atomic weight being	205

Iodic acid possesses the remarkable property of combining with other acids, and forming peculiar compounds. When sulphuric acid is added to it, a substance is precipitated, which seems to contain both, and which is decomposed by a strong heat, giving off iodine, oxigen, and sulphuric acid. The same happens with nitric, phos-

phoric, carbonic, and boracic acids; compounds of both are formed, which, when heated, give out iodine, oxigen, and the other acid, with which the iodic was in union.

Selenic Acid.

It has been already mentioned, that when selenium is heated in air, selenic oxid and acid are formed. Though the acid may thus be procured by synthesis, it is more easily prepared by boiling nitro-muriatic acid, or aqua regia, on selenium, by which oxigen is communicated to it, and selenic acid is formed, and may be obtained by evaporation.

As thus procured, it is a white saline-looking matter, which, when heated, becomes a vapour of the colour of chlorine, and again condenses in the cool part of the apparatus. Selenic acid has a sour taste. It is very soluble in cold, and in any quantity in boiling water, the solution as it cools depositing crystals. It is easily decomposed by those substances having a powerful affinity for oxigen; for instance, some of the metals, as iron and zinc, by which the oxigen is removed, and the selenium deposited.

According to Berzelius, it is composed of

selenium,	100.	or 71.25
oxigen,	40.33	or 28.75

and as 71.25 : 28.75 : : 50 : 20.1;
so that we may consider it composed of

1 atom selenium,	50
2 atoms of oxigen,	20
and its atomic weight will be	70

Cyanic Acid.

When sulphur, chlorine, and iodine, are heated with alkaline solutions, there is the formation of two acids, by the decomposition of the water, and transference

of its ingredients to the simple substances. A similar change is effected with cyanogen, for though Gay Lussac, (An. de Chim. xcv.) who first noticed the absorption of cyanogen, when passed through a solution of potassa, imagined that it united with the alkaline base, yet it has been found by the experiments of Wohler, (An. de Ch. et de Ph. xx. xxvii.) that it decomposes the water, and, by uniting with its ingredients, forms acids, one of which, from its containing oxigen, is called *cyanic*. The same acid is also formed and united with potassa, by exposing to heat a mixture of the salt called ferrocyanate of potass, and oxid of manganese, *(see Manganese,)* the one containing cyanogen in union with iron, the other a metal and oxigen, the latter of which, by the application of heat, unites with the cyanogen, and forms cyanic acid, which is left combined with the potassa of the salt. *(See Manganese.)*

The acid thus generated has not yet been procured in its separate state, for, from the apparently weak affinity by which its ingredients are held in union, when any acid is added to its salts with the view of removing the base, it is decomposed, and resolved into carbonic acid and ammonia, the former generated by the union of the carbon of cyanogen with the oxigen both of the acid and of the water, and the latter by the combination of the nitrogen of the first, and the hydrogen of the last. The same is the case also when the salt is heated, carbonic acid and ammonia being the products, and in this way, though Wohler failed in obtaining the acid, yet he succeeded in discovering the proportions of its ingredients. They are, according to him,

carbon,	15	or	2 atoms
nitrogen,	17.5	or	1 atom
oxigen,	10	or	1 atom

But 2 of carbon and 1 of nitrogen constitute cyanogen, so that cyanic acid is composed of

1 atom cyanogen,	32.5
1 atom oxigen,	10
and its atomic weight	42.5

Cyanogen and oxigen exist in a state of combination, apparently in the same proportions, in some of the fulminating metallic compounds, as that of silver; but in these it is supposed that a part of the metal acts as the medium of communication, and accordingly must be considered as an ingredient of the acid; the cyanogen and metal probably forming a compound radical in union with oxigen, and thus constituting the acid; an opinion strengthened by the fact that cyanogen is known to enter into union with iron, in its metallic state, and form a base acidifiable by hydrogen. *(See Iron.)* Liebig, (An. de Ch. et de Ph. xxiv.) was the first who threw out this conjecture with respect to the nature of fulminating silver, and from an analysis afterwards performed by himself and Gay Lussac, (Ibid. xxv.) it was found that the peculiar acid existing in it contained an atom of oxigen and of cyanogen; but in their attempts to decompose it, though the oxid of silver was separated by the addition of other re-agents, yet the acid always contained silver. They have given it the name of *Fulminic Acid*, to distinguish it from the cyanic of Wohler. *(See Mercury and Silver.)*

If these opinions of Gay Lussac and Liebig be hereafter established, it will be a confirmation of the remarks made (p. 282.), that there exist not only simple but compound bodies, acidifiable both by oxigen and hydrogen.

ACIDS WITH HYDROGEN.

Sulphuretted Hydrogen, or Hydro-Sulphuric Acid.

When sulphur is heated in hydrogen gas, they unite, and form a transparent colourless gas, called sulphuretted hydrogen, discovered by Scheele in 1777, since which it has been made the subject of investigation by Bergman,

Kirwan, and Berthollet, and more lately by almost all chemists of distinction of the present time.

Though sulphuretted hydrogen can be formed by the direct union of its ingredients, it is not prepared in this way for use, being always procured by the decomposition of water, by means of an acid and a metallic compound containing sulphur, such as sulphuret of iron or of antimony. *(See Iron.)*

Sulphuretted hydrogen is a transparent colourless gas, having a very fetid odour and taste, resembling that of putrid eggs. It extinguishes combustion, and is unfit for the support of animal life. Even when breathed largely diluted with air, it proves fatal in a very short time. Its specific gravity, according to Davy, is 1196, while Thomson makes it 1178; but from reasoning founded on the atomic doctrine, he says it ought to be 1180; 100 cub. inches weighing 35.9 grains.

When subjected to great pressure, it becomes a transparent, very limpid, colourless fluid, which, when exposed to the atmosphere, instantly flies off in the state of gas.

When electric sparks are passed through it, it is decomposed, sulphur is deposited, and pure hydrogen is set free, exactly of the same volume as the gas itself.

When heated in contact with air, it takes fire, and burns slowly with a pale bluish red flame, and sulphur is deposited on the sides of the vessel. If, however, it be previously mixed with oxigen gas, it explodes, and there is no deposition of sulphur; the proper proportions are, 2 of gas to 3 of oxigen, 1 of which unites with the hydrogen and generates water, while the other 2 combine with the sulphur to form sulphuric acid, which are the only products of the action.

From these experiments it is evident, that sulphuretted hydrogen has sulphur and hydrogen as its ingredients, and the decomposition by electricity shews that it contains its own volume of hydrogen; so that its proportions are easily ascertained, by deducting the sp. gr. of hydrogen from that of sulphuretted hydrogen, and the remainder is the quantity of sulphur.

1180 — 69 = 1111;
and as 1111 : 69 : : 20 : 1.24,
so nearly 125, that we consider it a compound of

1 atom of sulphur, -	20.
1 atom of hydrogen, -	1.25
and its atomic weight -	21.25

Sulphuretted hydrogen is easily absorbed by water, 100 cubic inches of which, according to Saussure, take up about 250. The solution is transparent and colourless, having the disagreeable odour and taste of the gas. It has the power of reddening vegetable blues, in this respect resembling the other acids already described. When exposed to the air, a part of the gas flies off, but another part is decomposed, and deposits sulphur, so that the solution becomes opake. On the addition of nitrous acid there is also a deposition of sulphur, the acid giving off oxigen to the hydrogen.

Sulphuretted hydrogen, in the gaseous form, is also easily decomposed by nitrous acid. If a few drops of the fuming acid be thrown into a jar of it, sulphur is instantly deposited, and the hydrogen combines with oxigen; and during their union heat is disengaged, sufficient to cause inflammation, particularly if the mouth of the vessel be loosely covered after the introduction of the acid.

Sulphuretted hydrogen acts very powerfully on almost all metallic substances, in general giving them a dark coating. Hence it is that silver goods are so easily tarnished, owing to the sulphureous vapours constantly floating in the atmosphere, and especially in apartments where coal is used as fuel, coal in general containing a considerable quantity of sulphur.

It is from the ease with which metallic matter, whether pure or in combination, is acted on by sulphuretted hydrogen, that they are used as tests of it. If, for instance, the smallest quantity of this gas should exist in any other gaseous body, it is easily detected by the introduction of a piece of white paper, soaked in solution of sugar of lead, which will instantly acquire a dark colour.

As sulphuretted hydrogen is in every respect to be considered an acid, not only because it reddens vegetable blues, but because it combines with alkalies and earths, and forms salts, it has been proposed by German chemists to call it *hydro-thionic acid*, (from *hydrogen*, and θειον, *sulphur*.) Gay Lussac has given it the name of *hydro-sulphuric acid*, a term rejected by English chemists, because it has been applied by Davy to oil of vitriol, which contains sulphuric acid and water. But those bodies containing water are called *hydrates;* it would be better, therefore, to adopt the name given either by the Germans, or that of Gay Lussac, as thus a great deal of confusion, particularly when treating of its compounds, would be avoided.

Sulphuretted hydrogen exists in many mineral waters, as those of Harrowgate, Moffat, Aix-la-Chapelle, &c. which are supposed to be efficacious in cutaneous diseases, from the sulphuretted hydrogen they contain.

Super-Sulphuretted Hydrogen.

Sulphur and hydrogen unite in other proportions than those in the preceding compound, and form another acid, called super-sulphuretted hydrogen. It cannot be procured by the direct union of its ingredients, but, on the addition of another acid to some of its compounds, it is liberated. Thus, when the solution of the salt formed by boiling sulphur in water of potass, and which is a compound of the alkali with super-sulphuretted hydrogen, *(see Sulphuretted Hydro-sulphuret of Potass,)* is poured into about its own bulk of muriatic acid, globules of an oily-looking fluid are gradually deposited, which are the acid set free from the potass. It is of a yellowish colour, has an odour similar to that of sulphuretted hydrogen, but not so offensive. When heated in air, it burns, and emits sulphurous acid.

According to Dalton, it contains double the quantity of sulphur that exists in sulphuretted hydrogen. If so,

it is a compound of two atoms sulphur, and one hydrogen.

We are little acquainted with it in its uncombined state, but when in union with salifiable bases, it forms interesting compounds, called *sulphuretted hydro-sulphurets.*

Muriatic or Hydro-Chloric Acid.

Muriatic acid has been long known as an important and useful acid. It is mentioned in the writings of Basil Valentine, who flourished in the fifteenth century. Mr Cavendish first obtained it in the state of gas, but was not aware of its composition. Its properties were afterwards examined by Priestley and Scheele, and more lately the investigation of its qualities, particularly with the view of ascertaining its composition, has occupied the attention of all the chemists of distinction of the present time. It was formerly called *spirit of sea salt,* and *marine acid,* which have given way to that of muriatic acid, derived from μυζια, salt water.

As usually procured, it is a liquid, more or less coloured from the admixture of foreign matter. In its pure state, however, it is a transparent colourless gas, having a peculiar pungent odour. When inspired, even though largely diluted with air, it irritates the fauces, and occasions a sense of suffocation. It is almost impossible to draw it into the lungs when pure, hence it is unfit for the support of animal life. It does not support combustion, a lighted taper, when immersed in it, being instantly extinguished. It has, however, a peculiar effect on the flame, which, just before it ceases, acquires a green tinge. This is best illustrated by putting the candle into a mixture of air and gas, so as to keep it burning, and for this purpose, having put a little sea salt at the bottom of a vase, pour on it a few drops of oil of vitriol. Muriatic gas will be disengaged from the salt, and mixing with the air of the vessel, will communicate a green tinge to a candle, when plunged into it.

The sp. gr. of muriatic acid gas has been variously stated. According to Biot and Arrago, it is 1250, while Thomson makes it 1284. When subjected to high pressure, Faraday found that it formed a transparent colourless fluid.

The proofs of the composition of muriatic acid gas are sufficiently strong. It has been already mentioned, (p. 261.) that when equal volumes of chlorine and hydrogen are mixed, they may be made to combine by heat, light, or electricity, and form a colourless gas, having all the properties of muriatic acid. When perfectly dry, muriatic acid gas has a series of electric sparks passed through it, part of it is decomposed, and chlorine and hydrogen are liberated. This experiment cannot, however, be conducted so long as to effect the decomposition of the whole of the acid, because, when the proportion of the newly disengaged gases becomes considerable, they are made again to combine by the electric spark. When muriatic acid and oxigen gases are passed through an incandescent tube, water and chlorine are the products. All of these experiments, and others of a similar nature, prove that muriatic acid is composed of hydrogen and chlorine, and hence the name *hydro-chloric acid*, proposed by the French chemists, but not adopted in this country. It has been mentioned, that when equal volumes of these are exposed to light, they form the acid gas, hence the proportions must be as their specific gravities, 69 to 2500,

and as 69 : 2500 : : 1.25 : 45,

so that it is composed of

1 atom of chlorine,	45.
1 atom of hydrogen,	1.25
its atomic weight being	46.25

As equal volumes of hydrogen and chlorine unite without condensation, the specific gravity of muriatic acid must be half the sum of the specific gravities.

$$\frac{2500 + 69}{2} = \frac{2569}{2} = 1284.5.$$

Muriatic acid gas, when exposed to air, emits apparently watery vapour, but which is owing to its combining with the moisture of the atmosphere.

It has a very powerful affinity for water, which takes up a large quantity of it, producing instant condensation. The rapidity of the absorption is well illustrated by removing, under water, the stopper from a tall bottle of it. The fluid instantly rushes up as if into a vacuum, and if, instead of water, cabbage infusion be employed, the colour becomes red. If a few drops of water be let up into a jar of gas standing over mercury, the absorption is slower, but still the whole of the gas is condensed, provided it is pure. Hence the necessity of working with it in a mercurial trough.

According to Davy, water absorbs 480, and according to Thomson, about 418 of the gas, forming a transparent colourless solution, usually known by the name of liquid muriatic acid, the specific gravity of which is about 1200 ; but this depends entirely on the quantity of gas it contains. During the absorption, there is an enlargement, 100 parts becoming about 134, and heat is disengaged.

When a piece of ice is admitted into the gas over mercury, it is instantly liquefied, as when thrown into boiling water, and the acid gas is at the same time absorbed.

Liquid muriatic acid, as the fluid procured by the condensation of the gas by water is commonly called, is, when pure, transparent and colourless. It has a pungent odour, similar to that of the gas itself. When exposed to air, it emits whitish fumes, occasioned by the escape of part of the gas, which then unites with the moisture of the atmosphere. Common muriatic acid of the shops is, however, rarely colourless, having in general a brownish tinge, owing to the presence of a little iron. Its specific gravity varies according to the quantity of gas it holds in solution. Tables of the quantity of acid in acids of different sp. gr. are given in the Appendix.

By applying a slight heat to the common muriatic acid, the gas is disengaged, and the water is left nearly

pure, hence a method of procuring the gas; and for this, all that is necessary is to put a little of it into a retort, and apply a slight heat, as that of a spirit lamp, by which the gas is disengaged, and may be collected over mercury. It is not, however, pure; it is loaded with moisture, but from which it can be freed, by exposing it to substances having an affinity for water, as muriate of lime.

The boiling point of the liquid acid depends, of course, on its strength; but, like other acids, there is a certain density at which it continues always the same. According to Dalton, acid of sp. gr. 1096, and which contains 1 atom acid + 16 water, or 20.4 per cent. of real acid, boils at 232, while that with either more or less requires a much lower heat. The boiling point of the acid of the shops, and which is composed of an atom of acid to 6 of water, is about 107.

When snow or ice, and liquid muriatic acid, are mixed, there is a great reduction of temperature, owing to the sudden liquefaction of the former. 5 of snow, and 7 of acid, previously cooled to 32, produce a cold of —27.

Muriatic acid, either gaseous, or when condensed by water, has no action whatever with the simple inflammables, in this respect differing from the oxi-acids.

The action between nitric and muriatic acids is important, not only from the peculiar nature of the action itself, but also from the remarkable properties of the compounds formed. When one of colourless nitric is mixed with two of liquid muriatic acid, they very soon acquire a brownish colour, and there is, at the same time, a disengagement of chlorine and nitrous acid. If a slight heat be applied, the action is accelerated, and the effervescence becomes violent, so that it is necessary to keep the flask under a chimney, to prevent the escape of the noxious vapour into the apartment. The heat must not, however, be long continued, otherwise the fluid again becomes colourless. The substance thus prepared has been long known by the name of *Aqua Regia*, from its power

of dissolving gold. It is now commonly called *nitro-muriatic acid.* It was at one time supposed to contain nitric and muriatic acids, both of which acted on the gold, the former giving it oxigen, and the latter combining with the oxid formed. It has been shewn, however, by Davy, that its power of dissolving this metal is owing to the presence of chlorine, derived from the decomposition of part of the muriatic acid, the hydrogen of which unites with oxigen from the nitric acid, to form water, setting free chlorine and nitrous acid, part of which escapes in the gaseous form, part is retained by the fluid. This fluid is a powerful solvent, not only of gold, but of some other metals, for which purpose it is used by chemists and metal refiners. *(See Gold and Platinum.)*

Muriatic acid has been detected in very minute quantity in the atmosphere, particularly near the sea, and in volcanic countries. It is a very abundant production in a state of combination, particularly in sea salt, and some earthy and metallic compounds.

It may be procured, as already stated, by the direct union of its ingredients, but it is never prepared in this way for use. It is always obtained by the addition of sulphuric acid to sea salt, which contains it in combination with soda. *(See Muriate of Soda.)*

It has been recommended to employ the gaseous acid, for purifying crowded or ill-ventilated apartments, but it is too irritating to the lungs to admit of its being used for this purpose. It may, however, be employed after the apartments are empty, *(See Muriate of Soda.)* The liquid acid is used in medicine as a gargle, when largely diluted. It is employed also in Pharmacy. It is very efficacious in removing iron stains from cloth; for which purpose the cloth is to be wetted with it, very much diluted, and almost immediately washed. Should the first application not succeed, it must be repeated, always taking care to wash the cloth well, lest the acid injure its texture.

Though muriatic acid has been treated of as being composed of chlorine and hydrogen, an opposite opi-

nion, with respect to its composition, is still maintained by some. They suppose that it is composed of oxigen and an unknown base, to which the name of *murion* has been given, and that this base, by uniting with an additional proportion of oxigen, forms chlorine, or rather, according to these chemists, *oxi-muriatic acid.* If this is really the constitution of these bodies, we can easily account for the chemical changes that take place, both with muriatic and oxi-muriatic acid. When hydrogen is mixed with the latter, it deprives it of its excess of oxigen to form water, which enters into union with the muriatic acid set free by the other being deprived of oxigen, so that, according to this doctrine, muriatic acid gas contains water as one of its ingredients. Again, when muriatic acid and oxigen gases are forced through incandescent tubes, water and oxi-muriatic acid are the products, the oxigen, according to the supporters of the old doctrine, uniting with the muriatic acid, and liberating the water.

Though the actions can thus so far be satisfactorily accounted for by both doctrines, yet there are some facts that seem more in accordance with that which supposes chlorine to be a simple body; besides, analogy is strongly in favour of this opinion; and by considering chlorine as a simple substance, we can adopt an arrangement in which the different facts of chemistry can be more clearly brought to view, than by supposing it to be compound.

Hydriodic Acid.

When iodine is heated in hydrogen gas, they gradually enter into union, and form a gaseous compound called hydriodic acid. Though it can thus be prepared by the direct union of its ingredients, other methods are preferred. That generally followed, is to put a mixture of 1 part of phosphorus and 4 of iodine, moistened, into a retort, *(see Cut, p. 315.)* and apply heat, by which there is a decomposition of the water, the oxigen uniting with the

phosphorus to form phosphoric, and the hydrogen with the iodine, to generate hydriodic acid; as it acts on water and mercury, being absorbed by the one, and decomposed by the other, it is most easily collected by the displacement of the air, and as it is heavier than it, the mouth of the receiver must be kept up.

This acid gas was discovered by Clement and Desormes, and has been examined by Dr Davy, and by Gay Lussac. It is transparent and colourless, having an odour similar to that of muriatic acid. Its sp. gr., according to Gay Lussac, is 4443, 100 inches weighing 133 gr. It is easily decomposed by oxigen, which, when heated with it, deprives it of its hydrogen. The same is the case with chlorine, which unites with the hydrogen to form muriatic acid, and sets free iodine.

The proportions of its ingredients are known by exposing it to the action of almost any metal, particularly mercury, which will combine with its iodine, and set the hydrogen at liberty. When this is done, the disengaged hydrogen occupies just half the volume of the gas itself, so that it contains half its volume of hydrogen gas, consequently, if we deduct half the specific gravity of hydrogen from that of hydriodic acid, we have the quantity of iodine with which the hydrogen was united:—

$$\frac{69}{2} = 34.5, \text{ and } 4443 - 34.5 = 4408.5$$

again, as $34.5 : 4408.5 :: 1.25 : 160$,

so nearly 155, the atomic weight of iodine, that we may consider it composed of

1 atom of iodine, -	155.
1 atom of hydrogen, -	1.25
and its atomic weight, -	156.25

The reason for the experimental result not agreeing with the atomic calculation, is the difficulty of procuring the hydriodic acid gas pure, so as to ascertain with precision its specific gravity.

Gases always unite in the simple ratio of volume to volume, or the one is a multiple of the other. If, then,

we suppose hydriodic acid to be composed of a volume of iodine vapour, and of hydrogen gas, united without condensation, the specific gravity must be the mean of these:

$$\frac{69+8611}{2} = 4340, \text{ and } 4340 - 34.5 = 4305.5$$

and $34.5 : 4305.5 :: 1.25 : 155.$

by which it is made to consist of an atom of each of its component parts.

Hydriodic acid gas is easily absorbed by water. The solution, when saturated, is of specific gravity 1700, and boils at 262½. When exposed to the air, it acquires a dark colour, from the deposition and subsequent solution of iodine, the oxigen uniting with the hydrogen, and setting the iodine free, which is immediately dissolved by the undecomposed acid. When chlorine is passed through it, muriatic acid is generated, and iodine deposited.

Though liquid hydriodic acid can be procured by the saturation of water with the gas, it is seldom prepared in this way. It is usually procured by passing a stream of sulphuretted hydrogen through water, holding iodine suspended in it, by which the sulphur is deposited, and the iodine and hydrogen unite to form the acid, which is taken up by the water. By boiling, the excess of water is driven off, and the acid obtained concentrated, which is known as soon as the boiling point becomes 262½.

Selenuretted Hydrogen, or Hydro-Selenic Acid.

Selenium, it has been already mentioned, unites with other bodies, and forms compounds called selenurets, some of which when thrown into water decompose it, the hydrogen uniting with the selenium, and the oxigen with the other body. When, to any of these compounds, muriatic acid is added, it unites with the oxid, and the compound of selenium and hydrogen is disengaged in the form of gas. It is called *selenuretted hydrogen*, or, as it is an acid, *hydro-selenic acid*.

It is absorbable by water, forming a transparent colourless solution, which reddens litmus, but which, when

kept for some time, becomes muddy from the deposition of selenium. The gas itself produces remarkable effects on the organs of respiration; when the smallest bubble of it is admitted into the nostrils, it excites pain, and destroys for some hours the sense of smell, followed by catarrh, deep pain of the chest, and expectoration of mucus, which continues for several days.

From the experiments of Berzelius, it is composed of

97.4 selenium.
2.6 hydrogen.

From which Thomson considers it composed of

1 atom of selenium,	50
1 do. hydrogen,	1.25
and its atomic weight will be	51.25

Fluoric Acid.

When sulphuric acid is added to the mineral called Derbyshire spar, a gaseous substance is given off, which so early as 1670 was observed to corrode glass. It was examined by Margraaf, who gave an account of it in 1768. Scheele also described its properties, and considered it a peculiar acid, being in the spar in union with lime. It was, however, afterwards shown by Wegleb, Bucholz, and Mayer, that the gas thus procured is not the acid in a state of purity, for when prepared in glass apparatus, it always contains a quantity of siliceous matter, derived from its action on the glass. Gay Lussac and Thenard first pointed out a method of obtaining it pure, and to them we are indebted for the account of its properties, (Recherches Ph. Chim.) Sir H. Davy and Dr Davy have also examined it, (Ph. Tr. 1812—13.)

Instead of carrying on the decomposition of the spar in glass vessels, the French chemists have recommended those of lead or silver, the vapour, as it comes off from the mixture of acid and spar, being also collected in receivers of the same materials. *(See Lime.)*

Fluoric acid, as procured in this way, is a colourless

fluid like water, the sp. gr. of which, when concentrated, is 1060. It has a strong affinity for water, and during its union gives out so much heat, as actually to cause the mixture to boil, and what is very remarkable, the specific gravity becomes increased, being, when containing a certain quantity, 1250. When the strong acid is dropt into water, it emits a hissing noise similar to that produced by the immersion of a red-hot iron.

It has been exposed to a cold of —4 without freezing. The boiling point has not yet been ascertained. When exposed to the air, it emits white fumes, having an odour similar to that of muriatic acid; and at the same time it quickly disappears, the vapour arising from it being very deleterious; so that great caution is necessary when experimenting with it.

It has a powerful effect on the animal fibre. When it touches the skin, it excites severe pain followed by inflammation and suppuration, leaving a sore very difficult to heal, and accompanied with general irritation; and hence the necessity of caution when operating on it.

The most remarkable property of fluoric acid, is its power of corroding glass, and of combining with its siliceous matter, *(see Silica.)* From this property, it is evident that we cannot keep it in vessels of this; metallic ones, as those of lead or silver must be employed.

Till very lately fluoric acid was supposed to be a compound containing oxigen. Ampere, however, first threw out the conjecture, (An. de Chim. et de Phys. ii.) that it might be a compound of hydrogen, and a base similar to chlorine and iodine, an opinion soon after adopted by Davy, and now maintained by almost all chemists. When describing the properties of Fluorine, it was then mentioned, that all attempts to procure it in its separate state have failed. We must, therefore, consider the views with respect to the composition of fluoric acid as not yet decided. Should they hereafter prove correct, the name of *hydro-fluoric acid* must be given it, shewing that it belongs to the class of *hydr-acids.*

Fluoric acid has been discovered in the Saxon and Bra-

zilian topaz, and in a few other minerals. Morrichini found it also in the enamel of the teeth of an elephant, and Gay Lussac in ivory; and Berzelius states that he has detected it, not only in the enamel, but also in the body of the teeth.

Fluoric acid, from its power of corroding glass, is employed for etching on it. For this purpose the glass is covered with a thin coating of wax, and that part to be corroded is exposed, by removing the coating by a sharp instrument. The fluor spar, reduced to powder, is put into a metallic vessel, and an equal quantity of sulphuric acid poured on it, by which the acid is set free; the glass is then put on, as a sort of cover, and secured by luting, leaving a small aperture for the escape of the superfluous acid. After being on for some time, that part uncovered by the luting is found to be corroded; if not sufficiently so, the process must be repeated.

Fluo-Boracic Acid.

When sulphuric acid is poured on a mixture of Derby spar and boracic acid, a gaseous fluid is given off, which was discovered by Gay Lussac in 1808, and afterwards examined by Dr Davy and Sir H. Davy, the latter of whom has concluded from his experiments that it is a compound of fluorine and boron, the former derived from the acid of the spar, the latter from the boracic acid, the hydrogen of the one and the oxigen of the other having united to form water. According to others, it is composed of fluoric and boracic acid in union, in atomic proportions, there being, as stated by Thomson, (First Prin.) an atom of each.

It is prepared by putting into a retort a mixture of 1 of finely powdered fused borax, and 2 of Derby spar, pouring on 12 of vitriol, and applying heat, by which the gas is disengaged, and may be collected over mercury.

Fluo-boracic acid gas is transparent and colourless, having an odour similar to that of muriatic acid; its sp. gr. 2370. When exposed to air, it emits white fumes. Water absorbs it quickly, taking up about 700 volumes,

and forming a transparent colourless fluid of sp. gr. 1770, which has a sour taste, and reddens vegetable blues. When exposed to heat, part only of the gas flies off.

Hydro-Cyanic Acid.

Cyanogen enters into union with hydrogen, and forms an acid, formerly called Prussic, now *hydro-cyanic*, which was first procured in a state of purity by Gay Lussac, to whom we are indebted for the fullest account of its properties, (An. de Chim. lxxxiii—xcv.) It cannot be procured by the direct union of its ingredients, so that, in preparing it, we are obliged to have recourse to decomposition. It has been already stated, (p. 281.) that cyanogen, like sulphur and chlorine, unites with metals, and forms compounds called cyanurets, and which, like sulphurets and chlorurets, are decomposed by water, the oxigen uniting with the metal, and the hydrogen with the cyanogen. In this way, then, compounds of oxids of the metals with hydro-cyanic acid are formed, and from which the latter may be procured by the addition of another, as muriatic. The cyanuret usually employed for this purpose is that of mercury, which is procured by the decomposition of another compound, containing cyanogen, not yet described, and in which the chemical action is very complicated. *(See Iron.)*

Hydro-cyanic acid, when pure, is a transparent colourless gas, unfit for the support of combustion and respiration. It is easily absorbed by water, in which state it is usually procured. It thus forms a colourless fluid of sp. gr. 7058 at 45, having an odour resembling that of peach-blossom. Its taste is at first cooling, but it soon impresses the tongue with a burning sensation. It is one of the most virulent poisons with which we are acquainted. It passes into vapour at the temperature of 80, and, what is very remarkable, congeals at 5, hence, when a little of it is exposed to the atmosphere, it is almost instantly frozen, the cold produced by the evaporation being sufficient to reduce the temperature of what is left

to the freezing point. When the vapour of hydro-cyanic acid, or when the gas itself, is exposed to heat in contact with air, it is inflamed; and when heated with oxigen, it explodes, carbonic acid, water, and nitrogen being the products. For complete combustion, 4 volumes require 5; by which 4 of carbonic acid and 2 of nitrogen gases are formed, while the remaining elements produce water. 4 volumes of carbonic acid are composed of 4 of oxigen, and 4 of carbon vapour, the remaining 1 of oxigen must have united with 2 of hydrogen, so that 4 volumes of acid must be composed of 4 carbon vapour, 2 nitrogen, and 2 hydrogen; but 4 volumes carbon and 2 of nitrogen constitute 2 of cyanogen, so that it is composed of equal volumes of cyanogen and hydrogen, combined without condensation; the proportions by weight must therefore be as their specific gravities, 1805.5 to 69.4.

And as 1805.5 : 69.4 : : 32.5 : 1.25.

So that it is composed of

1 atom of cyanogen,	-	32.5
1 atom of hydrogen,	-	1.25
its atomic weight being		33.75

As the gas is composed of equal volumes of cyanogen and hydrogen united without condensation, its specific gravity must be

$$\frac{1805.5 + 69.4}{2} = 937.4$$

Hydro-cyanic acid, when long kept, undergoes decomposition. Carbon is deposited, and ammonia, formed by the union of the hydrogen and nitrogen, is disengaged. It is also decomposed by passing it through incandescent iron tubes, carbon being deposited, and hydrogen and nitrogen evolved.

Sulpho-Cyanic Acid.

Hydro-cyanic acid has no action with simple inflammables except with sulphur, with which it seems to enter into union, and form an acid, discovered by Porret in 1808, but who was not then aware of its composition. In 1814

he published an account of it, (Ph. Tr.) and then concluded that it was a compound of hydro-cyanic acid and sulphur. He gave it the name of *sulphuretted chyazic acid*, but for which *sulpho-cyanic* has been substituted.

Though it may be prepared by putting sulphur into hydro-cyanic acid, it is never procured in this way for use. It is generally obtained by the decomposition of some of the compounds of iron with cyanogen. *(See Iron.)*

Sulpho-cyanic acid is a transparent fluid, with a slight tinge of pink, and an odour similar to that of strong vinegar. Its specific gravity is 1022. It boils at about 216, and by the abstraction of heat, freezes at 54. When passed through incandescent tubes, it is decomposed, and if these contain iron shavings, sulphuret of iron is formed, and hydro-cyanic acid and sulphuretted hydrogen are evolved.

From the analysis of a compound of sulpho-cyanic acid and oxid of copper, Mr Porret concludes, that it is composed of 2 by weight of sulphur, and 1 of hydro-cyanic acid; while Dr Thomson supposes it contains 2 atoms of the former, and 1 of the latter.

According to Berzelius, on the contrary, the sulphur and cyanogen are united, forming a compound base, with which the hydrogen is combined. He supposes its composition to be

1 atom of cyanogen = 32.5
2 atoms of sulpur = 40.

forming 1 atom of *bi-cyanuret of sulphur* = 72.5
which is in union with 1 atom of hydrogen = 1.25

So that if his views are correct, sulpho-cyanic acid is composed of

1 atom bi-cyanuret of sulphur, 72.5
1 atom hydrogen, - - - 1.25

its atomic weight being 73.75

If this is really its composition, it must be considered a *hydr-acid*, containing a compound base, and which is

not at all improbable, as it is well known that cyanogen has a tendency to unite with other bodies, and form compound acidifiable substances, of which we have a good instance in the case of iron, with which cyanogen forms a base called *ferro-cyanuret*. Sulphur and cyanogen thus uniting will form *sulpho-cyanuret*, and its compound with hydrogen, if the views of Berzelius are correct, must be called *hydro-sulpho-cyanic acid*.

Chloro-Cyanic Acid.

When chlorine gas is passed through liquid hydrocyanic acid, there is also decomposition, and another acid is formed, which was discovered by Gay Lussac, and called by him *chloro-cyanic acid*.

It may be prepared by passing a stream of the gas through the liquid, till there is an excess of chlorine, which is known by its destroying colour. The solution is then agitated with mercury to remove the superfluous chlorine, and by the application of heat to it in a retort, a gaseous substance is given off, which is the acid, but supposed to be mixed with carbonic acid. Gay Lussac obtained it concentrated in the liquid state, by putting it into a tall glass with mercury, which he inverted on a cup of the same fluid. The whole was put under the receiver of a pump, and the air withdrawn, by which the mercury and hydro-cyanic acid escaped from the glass, but left it full of acid vapour. On the introduction of the air, the vapour was condensed, the mercury at the same time rising, and bearing the fluid acid above it.

As thus obtained, it is a transparent colourless liquid, having a very pungent odour and acid taste. Its vapour is also transparent and colourless, being extremely irritating to the eyes. When mixed with oxigen and hydrogen, it explodes by electricity. According to the analysis of Gay Lussac, it is composed of

2 vol. carbon,
1 vol. nitrogen,
1 vol. chlorine,

that is, of 1 vol. cyanogen,
1 vol. chlorine.

Hydro-Xanthic Acid.

It has been already mentioned, (p. 281.) that when bi-sulphuret of carbon is treated with alcoholic solution of potassa, the alkali becomes neutralized with a peculiar acid, containing hydrogen carbon and sulphur, the two last forming a compound radical, called *xanthogen*. When to the solution concentrated by evaporation, muriatic or sulphuric acid is added, an oily-looking fluid is separated, which is the acid previously in union with the potassa, the other acid, owing to its more powerful affinity, having disengaged it from its state of combination.

Hydro-xanthic acid, according to Zeisse, (An. of Phil. N. S. iv.) is a transparent, colourless, oily-looking fluid, of greater specific gravity than water, having an acid taste, and a strong peculiar odour. When heated to about 212, sulphuret of carbon is deposited, and an inflammable gas is disengaged. When heated in air, it burns and emits the odour of sulphurous acid. When mixed with iodine, it is decomposed, sulphuret of carbon is deposited, and the fluid has the properties of hydriodic acid. It is from this and other experiments that Zeisse has concluded, that the acid contains hydrogen in union with a sulphuret of carbon, which acts the part of a base.

SECTION VI.

ALKALIFIABLE BODIES.

THE alkalifiable bodies, or those forming *salifiable bases*, may, like acidifiable substances, be divided into two great classes.

Those forming bases with oxigen.

Those forming bases with hydrogen.

To the latter belongs *nitrogen*, the properties of which have been already so far described as included in the class of acidifiable bodies; but it combines also with hydrogen, and generates the alkali *ammonia*. To the latter belong those substances long called *Metals*, and to which have lately been added the newly discovered bases of the alkalies and earths. They have properties in common, and by which they are distinguished from other substances; so that, before proceeding to treat of them individually, a great deal of unnecessary repetition will be avoided, by giving an account of them in general.

The metals, with the exception of the bases of the alkalies and earths, are of great specific gravity, the lightest being about 6 times, and the heaviest at least 21 times the weight of water.

They are possessed of considerable tenacity, by which they are *malleable* and *ductile*. By ductility is meant

that property by which they can be drawn out to wire. Wires are formed by drawing a rod of metal through conical holes in a metallic plate, each hole being smaller than the preceding one. By malleability is understood that quality by which they may be beat by a hammer, or extended by rollers into thin leaves.

The metals vary much in ductility and malleability; some scarcely possessing them, except at a certain temperature, while others have them in a remarkable degree. Thus, a grain of gold can be beat out, so as to cover 56 square inches, and an ounce, it is said, may be drawn on silver wire, to the length of about 1300 miles. During these processes, they become brittle and liable to break; but which is prevented by heating them to redness, and allowing them to cool slowly, as by surrounding them by ashes, or by a bad conductor, by which they are prepared for undergoing the same process as before. This is called *annealing*.

Metals are in general elastic. In hardness they are inferior to many of the earthy bodies, but some of them have it to a considerable degree.

With respect to caloric they are good conductors, and they expand more than other solids, their expansion being also much more equable. According to Dulong and Petit, that of mercury from 32 to 212 is uniform, keeping pace with the addition of heat; but at degrees above or below this, it is by no means as the increase of temperature.

By the application of heat they may be fused, but the melting point is various. Mercury continues fluid at —40. Tin melts at 442; while platinum requires for its fusion the most intense heat we can procure. Those which are liquefied at comparatively low temperatures, may be volatilized and condensed, unchanged in their properties, in the cool part of the apparatus, provided the air is excluded, as is the case with potassium, sodium, mercury, zinc, and some others.

When they have been fused, and allowed to congeal slowly, they assume a crystalline form, the crystals in

general being four-sided pyramids, either single or double, but they are occasionally also prismatic or cubical. During their passage from fluid to solid, many of them expand, and hence it is that they take so fine an impression when cast into moulds.

Metals are conductors of electricity, and they possess also, in a remarkable degree, when acted on by other substances, the power of generating, and conveying when generated, galvanic electricity.

They have attractions for almost all other substances, particularly those, the properties of which have been already described.

When heated in air, they in general lose their splendour and malleability, become friable and heavier, and resemble in appearance an earthy substance. This process, formerly called *calcination*, is now termed *oxidation*, because it is known to be occasioned by the union of the metal with the oxigen of the air, and the product is called a *calx* or *oxid*. The temperature at which it occurs, varies in almost every different instance. In some it goes on slowly, in others with great rapidity. In some it is accompanied with a slight glow, but in others it puts on the appearance of combustion, of which we have a good example in zinc. To oxidate it, we have merely to put it into a ladle, and place it on a fire. It at first melts, but on continuing the heat, and stirring the melted metal, it begins to burn with a feeble flame; but when the heat becomes more intense, the combustion is very brilliant, and a white flaky matter is wafted up, while an earthy-looking substance remains in the vessel. These are the products of the action, a compound of zinc and oxigen. It is evident, that since this process depends on a union of the metal with oxigen, it must become heavier, while at the same time the air must be diminished; and that this is actually the case, has been satisfactorily proved. If a piece of copper, after being weighed, be kept in a fire for some time, and again weighed, it will be found considerably heavier; but, for the success of this experiment, it is necessary, on remov-

ing it from the fire, to put it on a plate, and cover it with a shade till it cools, because scales of the oxid fly off.

When a metal is heated in oxigen gas, the combustion becomes very brilliant, and it can be shewn, at the same time, that the gas is consumed. For this purpose, into a jar of the gas, *(Cut, p. 173.)* open at both ends, and standing on a plate of water, introduce a coil of very fine iron wire, the end of which being tipt with sulphur, is previously kindled. It instantly becomes red hot, and is gradually consumed, emitting a bright white light; at the same time, if the cork to which it is fixed is tight, the water will rise, and fill the jar. Globules of a black substance are found in the plate, which are the iron in union with oxigen; and that they are so, is proved by heating them in a retort along with charcoal, by which carbonic acid gas is given off, and metallic iron is left.

The metals combine with different proportions of oxigen, and even the same metal is susceptible of different degrees of oxidation. Of course, like other compounds, the ingredients are determined by atomic proportions.

As the metals unite with different proportions of oxigen, it is necessary to characterise them by particular names. This is occasionally done by prefixing the colour, or some of their qualities, as black and red oxid of iron; but the method now in general use, is that applied to the other oxids which have been already described: As *protoxid*, that with the first; *deutoxid*, with the second; *tritoxid*, with the third; *peroxid*, with the largest proportion of oxigen.

The oxids differ much in their appearance. They have not the lustre, tenacity, nor specific gravity of the metal; indeed, they in general resemble an earthy substance. They are not inflammable, and they are less fusible than the metal they contain.

When a metal has been oxidated, it may be restored to its metallic state, in some cases by the mere application of heat, in others by heating them with coal or charcoal, which, as has been mentioned with respect to that

of iron, deprives them of their oxigen, to form carbonic acid, that is given off in gas. This is called *reduction*, and the matter subjected to the process is said to be *reduced*, or *revived*.

The action of metals with water is very different. Some of them, as the lately discovered bases of the alkalies and earths, deprive it of its oxigen the moment they come in contact, at the same time liberating the hydrogen. Others, as iron, require a high temperature for effecting the decomposition, while some, even though brought to a red heat, have no effect on it; the affinity between the oxigen and hydrogen being more powerful than that between the oxigen and metal.

The metals enter into union with some of the acidifiable bodies, and form substances possessed of peculiar properties.

Compounds of metals and carbon may be formed merely by heating them together, as when iron is heated, imbedded in charcoal powder. The products are called *carburets*, and do not differ much in their properties from the metals themselves.

Phosphorus also unites with metals. The compounds called *phosphurets* may be prepared either by heating the phosphorus and metal together, excluded from air; or, which is better, by heating the metal with phosphoric acid and charcoal, by which the carbon deprives the acid of its oxigen, and the disengaged phosphorus unites with the metal, and forms a phosphuret. Phosphurets are usually soft, more fusible than the metals of which they are composed, and are in general decomposed by a strong heat.

The action of many of the phosphurets with water, is important. When brought into contact, there is a double decomposition, the oxigen combining with the base, and the hydrogen with the phosphorus; so that oxid of the metal and phosphuretted hydrogen are the products. This action takes place only with those phosphurets which contain metals having a powerful affinity

for oxigen, as the bases of the alkalies and earths. The phosphurets of other metals are not affected by water.

Sulphur unites readily with metals, and forms important compounds. The union is effected by heating them together, excluded from air. Thus, if 3 by weight of iron filings be heated in a flask with 1 of flowers of sulphur, when the latter is liquefied it begins to unite with the former. During the union there is at first a beautiful glow over the mixture, but at last the whole becomes incandescent, and continues so for some time. The compound formed is a *sulphuret*, known also in commerce by the name of *pyrites*.

The sulphurets retain some of the metallic properties. They have, in general, considerable lustre, but they are not malleable or ductile, and they are usually more fusible than the metal they contain. Many of them are decomposed by a strong heat, the sulphur being expelled, and leaving the metal pure. They are all decomposed when heated in air, the sulphur being inflamed, and passing off in the state of sulphurous acid, while the metal is itself converted into an oxid. Many of them are decomposed also by water, and the action here is important. When, for instance, the compounds of sulphur and some of the bases of the alkalies or earths are thrown into water, the hydrogen unites with the sulphur, to form sulphuretted hydrogen, and the oxigen with the metal, to generate an oxid, which having an attraction for each other, enter into union, and a salt is the product.

Those sulphurets which are not acted on by water, are, in general, decomposed by it provided an acid is present, as when sulphuret of iron and diluted sulphuric acid are mixed. The action on the sulphuret and water is the same as already mentioned, but instead of the sulphuretted hydrogen uniting with the oxid, it is driven off in the form of gas, being prevented from entering into union with it, from the more powerful affinity of the other acid.

Some of the metallic sulphurets, when exposed to mois-

ture and air, are ultimately converted to *sulphates*, or compounds of the oxid and sulphuric acid, the water being first decomposed, and forming sulphuretted hydrogen and oxid, which when united decompose the air, the oxigen uniting with the hydrogen to generate water, and with the sulphur, to form sulphuric acid, which is left in union with the oxid, thus producing sulphate.

The sulphurets or pyrites are a very important class of compounds, not only from their peculiar properties, but also from the metals being frequently found in this state of combination.

Chlorine acts easily on metals in general, and forms compounds called *chlorids*, or *chlorurets*, analogous in their properties to sulphurets. When, for instance, copper leaf is introduced into a bottle of chlorine gas, it is instantly inflamed, the chlorine and copper uniting to form chloruret. The easiest mode of introducing the leaf is to put it coiled up loosely into a small copper dish, and place this on a wire, one end of which is passed through a cork, the other bent so as to form a support for the dish. The bottle of gas should be placed in a plate of water, and a shade put over it when the leaf is introduced, that the fumes may be prevented from escaping.

Chlorurets in many respects resemble sulphurets, particularly in their action with water. When, for instance, the chloruret of a metal, having a powerful affinity for oxigen, is thrown into water, there is an immediate decomposition, the oxigen and metal combine to form oxid, and the hydrogen and chlorine muriatic acid, which entering into union with the oxid produces *muriate ;* so that chlorurets, properly speaking, are not soluble in water, but converted into muriates. There are chlorurets, however, which do not undergo this change, such as those of silver and mercury, but on the addition of an acid, or of a metallic oxid, the decomposition is effected, the hydrogen uniting with the chlorine, and the oxigen with the metal. If another acid has been added, it combines with the oxid, and the muriatic acid is disengaged,

but if another oxid has been employed, it seizes the muriatic acid, and the newly formed oxid is set at liberty.

The action of iodine is similar to that of chlorine and sulphur,—it unites with the metals, and forms *iodurets*. The union may be effected either by putting the metal, as potassium, into the vapour of iodine, by which it is inflamed, and then combines with it, or by mixing them, and heating them, by which the union is also effected. Iodurets are similar, in many respects, to sulphurets and chlorurets. When thrown into water, most of them are decomposed, the oxigen forming an oxid with the metal, and the hydrogen hydriodic acid with the iodine, and these by their union generate a salt.

Cyanogen acts exactly in the same way; with some it enters into union directly, but with others it cannot be made to combine, except by decomposition. The compounds formed are called *cyanurets*, and are, when acted on by water, similar to chlorurets, being converted to hydrocyanates.

The acids in general act with metals with great ease, but the action differs according to the acid, and its state of concentration; the diluted acid generally acting most energetically. When nitric acid is employed, either concentrated or diluted, the metal, with few exceptions, is dissolved, but at the same time acquires oxigen from part of the acid to form an oxid, which uniting with the remainder, generates a salt, nitric oxid being disengaged. When sulphuric acid concentrated is used, there is no action at a natural temperature; but on the application of heat, part of the acid is deprived of oxigen, to form an oxid, which unites with the remainder of the acid. If, however, it be diluted, the action is altogether different. It is not the acid but the water that gives oxigen to the metal, to form the oxid,—of course hydrogen gas is disengaged. A similar action takes place with muriatic acid, the water oxidizing the metal.

The substances formed in this way are called *salts*, which, it must be borne in mind, *are compounds of the acid and metallic oxid*, for in no instance does an acid unite

with a metal. In most of these the properties of the acid and base are destroyed or neutralized; and when this is the case, the compound is called a *neutral salt.*

Compound salts differ much from each other in appearance.—Some of them crystallize easily, while others cannot be procured in that state. Most of them are transparent and colourless, but some are of different colours, more particularly those containing the substances long known by the name of metals.—Thus the salts of copper are blue, those of cobalt, red.

As metals unite with different proportions of oxigen, so we find that there are salts containing the same metals, but in different states of oxidation. In general, when a metal is dissolved by an acid, diluted, it is in the state of protoxid; but on the contrary, when concentrated, the oxid is at its maximum. Gay Lussac has laid it down as a general rule, that the more oxigen there is in an oxid, the more acid it requires for saturation.

It is of the utmost consequence to distinguish the salts by particular names; for as there are compounds of the same acid, with the metals in different states of oxidation, and again the same oxid in union with different proportions of acid, unless particular names be given to the compounds, it would lead to a great deal of confusion.

The name of a salt is in general derived from that of the acid and base which it contains,—that of the acid being considered as the *generic* name. Thus, those with *nitric* acid, are called *nitrates;* those with *sulphuric* acid, *sulphates*, and so on; and to these is added that of the base, as *sulphate of soda*, *carbonate of lead*, &c. It must be kept in mind, however, that though we speak of a salt of a metal, it is always understood that that metal is in the state of oxid;—thus carbonate of lead, properly speaking, is carbonate of *the oxid of lead.* As the acidifiable bodies are susceptible of different degrees of acidification, and the acids formed enter into union with the metallic oxid, it has been recommended that the name denoting the acid should have a different final syllable, by which the proportion of oxigen may be shewn, and

the acid pointed out. Thus, those salts with the acid having the largest proportion of oxigen, have the final syllable of their name in *ate*, and those with the smaller proportion, in *ite;* as *sulphate*, denoting that the salt contains *sulphuric acid*, and *sulphite*, that it has *sulphurous acid*. But, again, the same acid frequently enters into union in different quantities with the same base. When the properties of both are destroyed, the salt is called a *neutral* one. When the acid is in excess, and in which case the compound has acid properties, it is called a *supersalt*, as *supersulphate* of potass. When it is in deficiency, and of course has the properties of the base, it is termed a *subsalt*, as *subcarbonate* of soda. Instead of *super*, the latin words *bis*, *ter*, &c. are sometimes used to shew the relative quantity of acid; thus, *bisulphate* of potass, that containing twice as much acid as exists in the sulphate. As metals are susceptible of different degrees of oxidation, and as the different oxids unite with the acids, it is necessary also to shew by the name which oxid the salt contains,—and this is done either by prefixing the term by which the oxid itself is characterized, or by adding some of its qualities. Thus, when a protoxid unites with acid, it forms a *protosalt;* as *protosulphate* of iron, a compound of sulphuric acid and protoxid of iron. When the acid is in union with a peroxid, it forms a *persalt;* as, *persulphate* of iron. We often speak, also, of the *green* sulphate, and *brown* sulphate of iron, the former having the protoxid, the latter the peroxid; but the other method is preferred, because it points out the composition of the salt.

Metals unite with each other, and form compounds called *alloys*, with the exception of those containing mercury, which are termed *amalgams*, and to designate these the name of the metal in largest proportion is placed first. Thus, an alloy of gold and copper shews that the gold is in largest quantity.

Alloys retain the general metallic properties, but those of the metals they contain are considerably altered. Thus,

the specific gravity, hardness, and fluidity, are different from what should be expected. The specific gravity, for instance, is seldom the mean of those of the ingredients, being in general greater; but in some cases it is less, as with the alloys of gold with copper or tin. With respect to fusibility, we find that this is also changed, the fusing point being, in general, far below that of the least fusible metal. Platinum, which requires a most intense heat for its liquefaction is melted easily when united with other metals.

The malleability and ductility are, in general, also much impaired. Gold and lead are both malleable and ductile; the former more so than any other metal, but when they are alloyed together, the compound is quite brittle; indeed, the ductility and malleability of gold are diminished by the presence of 1-2000th part of lead. Hence the necessity of being particular in the purification of metals.

By alloying metals there is also a remarkable change with respect to their power of being oxidated and dissolved in acids. In general they are more easily oxidated when in union than when pure, owing, as some suppose, to a galvanic action being excited. With respect to their solubility, in some instances, metals which are acted on by acids with difficulty, are easily affected when alloyed; while others, which are easily acted on, are enabled, by their union with others, to resist, in a great measure, their action. Thus, silver is easily dissolved by nitric acid, but when united with gold, it is not affected, unless when in large quantity; and hence when it is necessary to separate them, as in the methods practised for procuring them, if little silver is present, the alloy must be fused with an additional proportion.

Metallic oxids unite with each other, and form an interesting class of compounds, which, from their colour, are now employed in imitating the gems. This is particularly the case with the oxids called earths, and those of the common metals.

Metals are found in various states, occasionally *native*,

that is, metallic, but more frequently in combination, as with oxigen, sulphur, or acids, in which form they are called *ores*. The most common natural compounds are those with sulphur, which are called *pyrites*, and it is from these that metals are most generally obtained. The process of extracting them from their ores, is called *reduction* or *smelting*.

Different methods are practised, depending in a great measure on the nature of the metal, and the substances with which it is combined. In general, the metallic compound is first separated as much as possible from the earthy impurities in which it is imbedded, and which is done by breaking the ore into fragments, and removing the earthy matter, the process being in some cases accelerated, by putting the coarse powder on an inclined plane, and allowing a stream of water to flow on it, by which the heavier metallic ingredients are carried to the bottom, the lighter stony impurities remaining above. When the ore contains sulphur, it is then roasted, by which this is driven off, and the metal united with oxigen; after this the oxid is mixed with coke, or charcoal, and again subjected to heat, by which the oxigen is removed, and the metal left pure, and being melted, falls to the bottom of the furnace, and is drawn off. When it is a volatile one, it is procured by sublimation. The particular processes followed in procuring the different metals, will be described when giving their chemical history.

General Properties of Compound Salts.

The salts formed by the union of the acids and bases, whether containing oxigen or hydrogen, have properties by which they are distinguished from other bodies. A general account of them may be useful, not only as pointing out those qualities by which they are characterized, but as saving hereafter a great deal of useless repetition.

When an acid is added to a salifiable base, they unite, frequently with the evolution of heat, and in most instances the properties of both are destroyed or neutra-

lized, and hence it is that the compounds formed have been called *Neutral Salts.*

That there is a change of properties, that the compound no longer possesses the qualities of its ingredients, is easily shewn. The distinguishing character of an acid is its changing the vegetable blues to red, so that, if a few drops of any of them, say sulphuric acid, is added to the colouring matter, it is reddened. The distinguishing feature of a salifiable base, when soluble, is its making the blue green; hence, on adding a few drops of solution of soda to the same infusion, it becomes green. As sulphuric acid will combine with soda, if we add the infusion containing acid to that having the alkali, they unite, and the original colour returns, shewing that the compound has no power of changing vegetable blues; so that properties of the acid and alkali have been destroyed.

Many of the compound salts are soluble in water, while others are not acted on by it; in other words, they are insoluble. The former, when in solution, may in general be made to yield crystals by slow evaporation, the crystal varying in different cases, not only with respect to form, but also to constitution; for many of them have a large quantity of water in chemical union with their particles, while others have very little, indeed some of them are free from it. The water thus retained is called *water of crystallization*, and the difference in the quantity gives rise to particular properties.

Thus, when a moderate heat is applied to those containing much of it, they at first liquefy, but on the continuance of the heat, are again consolidated. Glauber salt, heated in a flask over a lamp, becomes quite limpid, like water, but afterwards forms a dry white cake. The fluidity in this instance is owing to the salt being dissolved in its water of crystallization, and hence it is called *watery fusion*, to distinguish it from fusion occasioned merely by heat.

Those salts, on the contrary, which have little water, crackle when heated, and the parts are separated, and

scattered about. Sea salt thrown on a fire, or on a hot iron plate, has this effect. It is owing to the water in the salt being suddenly converted to vapour, the expansive force of which separates the particles with a crackling noise; hence it is called *crepitation*, (*crepito*, to *crackle.*)

Some of the neutral salts, when exposed to the atmosphere, absorb moisture, and become fluid. Thus, carbonate of potassa, or potashes, when strewed on a sheet of blotting paper, very soon exhibits signs of becoming moist. This is called *deliquescence*, (*deliquesco*, to *become moist.*)

Other salts, as carbonate of soda, or what is commonly called soda, when exposed to the air, lose their transparency, and acquire a white crust on their surface, and if left long enough, fall into a white powder. This is owing to their losing their water of crystallization, which is taken away by the air. It is called *efflorescence*, (*effloresco*, to *blow as a flower.*) These changes point out the necessity of keeping the salts excluded from the atmosphere, which thus alters so much their properties.

Though some of the compound salts are soluble, and others insoluble in water, several are decomposed by it, the water uniting with the greater part of the acid, still retaining a little of the base; while the remainder of the base is precipitated, but still combined with a little of the acid, thus apparently converting the salt into a *soluble supersalt*, and an *insoluble subsalt.*

Heat decomposes some of the compound salts, particularly nitrates, carbonates, sulphates, and all those containing hydr-acids; the action, however, varies in different cases. When a salt, with an *oxi-acid*, is decomposed by heat, the acid is in general expelled without being decomposed, leaving the base pure, though to this there are a few exceptions, the whole, or part of the acid, in some instances, communicating an additional proportion of oxigen to the metal, so as to bring it to a higher state of oxidation. The action with the salts containing hydr-acids is, however, different and peculiar. When any of

these is exposed to heat, both the acid and base are decomposed, the hydrogen of the one, and oxigen of the other, uniting to form water, and leaving the metal and radical of the acid in union, so that the residuum is a *sulphuret*, *chloruret*, or *ioduret*. This must be considered a general rule, and is just the converse of what has been already stated with regard to sulphurets, chlorurets, and iodurets, which, when thrown into water, become hydro-sulphurets, muriates, and hydr-iodates.

This is not, however, the case with those salts containing ammonia, or the *hydr-alkali*. On the application of heat, there is no decomposition of this kind; for though the base of the alkali may have a tendency to combine with that of the acid, yet there is no oxigen to unite with the hydrogen, and by which the decomposition of the hydr-acid salts with oxidized bases is effected.

Some of the compound salts are decomposed by exposure to air, particularly those, the acids and bases of which have a strong disposition to unite with more oxi- Thus hydro-sulphates gradually become sulphates, and some of the carbonates combine with an additional proportion of acid. When the salt contains a metal in a low state of oxidation, but capable of combining with more oxigen, there is in general, on exposure to air, an absorption of this gas, by which the metal becomes peroxid, and part of it is deposited; because the acid which previously neutralized the protoxid, is not in sufficient quantity to keep the peroxid in solution; for it must be borne in mind as a general law, that the more oxigen there is in the oxid, the more acid it requires for neutralization. Proto-sulphate of iron, or green vitriol, undergoes this change.

Some of the simple acidifiable bodies, as phosphorus and carbon, decompose the salts, combining with the oxigen, and causing the deposition of the metal in its metallic state.

By far the most important actions on compound salts are those accomplished by the addition of acids and sali-

fiable bases. When an acid is added, between which and the base there is a stronger attraction than that between the ingredients previously in union, there is an immediate decomposition; the acid introduced combines with the base, and sets the other at liberty. Thus sulphuric acid liberates nitric and muriatic acids from nitrates and muriates, and almost any acid will decompose a carbonate, disengaging the carbonic acid. In some, the action is much more complicated; but these particular cases will be afterwards noticed, when describing the salts in which they occur.

The preceding remarks apply only to the addition of *oxi-acids* to salts. A much more complicated action, in general, ensues, when *hydr-acids* are employed; because, owing to the powerful affinity between oxigen and hydrogen, water is frequently formed, and the metal and base of the acid are left to enter into union. Thus, when muriatic acid, or sulphuretted hydrogen, is added to some of the salts, as those of lead, silver, &c. there is not only the separation of the oxid and acid, but the hydrogen of the hydr-acid and oxigen of the oxid combine to form water, while the chlorine, or sulphur, unite with the metal, so that the product is a chloruret or sulphuret, the other acid remaining in solution. The same is the case with hydr-iodic and hydro-cyanic acid, the precipitates formed by them being iodurets and cyanurets.

Some of the compound salts are decomposed by metals, provided one be employed which has a more powerful affinity for oxigen than that of the metal in solution. Thus iron, put into a solution of blue vitriol, or sulphate of copper, unites with the oxigen of the oxid, and with the acid itself, to be converted into a sulphate, while metallic copper is deposited. Though this is generally ascribed to the superior force of attraction of the introduced metal for oxigen, some are inclined to think that the action is galvanic, and much more complicated than that stated. *(See Galvanism.)*

Metallic salts are decomposed by the salifiable bases, provided the attraction between the base added, and the

acid of the salt, is more powerful than that between the ingredients in union, so that they unite, and the base is set at liberty. Thus the soluble oxids, as potassa, soda, and lime, decompose almost all salts, because their affinity for acids is more powerful than that of the acids for the other bases. The newly liberated oxid will be either precipitated, or held in solution, according as it is soluble or insoluble in water. In some cases, the base, though precipitated, almost instantly disappears, being dissolved by an excess of the other. Thus potassa, which decomposes the salts of alumina, of lead, and zinc, if used in a large quantity, dissolves the precipitated oxid; but from the solution, the oxid may be thrown down by the cautious addition of an acid, which will neutralize the dissolving oxid.

In considering the alkalifiable bodies, they may be divided into the two classes already mentioned,—those uniting with oxigen, and those uniting with hydrogen; and it is the properties of the first only that are to be described. It is customary to arrange them in subdivisions, according to their properties; such as their action with heat and air, their malleability and ductility, or their power of being dissolved by acids. Without attempting any arrangement of this kind, their properties may be perhaps more distinctly stated by dividing them into the three classes of

Metals producing *alkalies*,

Metals producing *earths*, and

Metals producing compounds, long known by the name of *metallic oxids*.

By adopting this, we still adhere to the old arrangement of alkalies, earths, and metals, and are thus, after detailing a few of the properties of the metals with oxigen, chlorine, sulphur, and some other bodies, to describe the compounds long called neutral salts, and the earthy and metallic salts.

The following is the order in which the simple bodies forming bases, are to be treated of:

1*st*, Substances forming those long known by the name of *alkalies*.

1. Potassium.
2. Sodium.

2*d*, Those forming *earths*.

1. Calcium.
2. Barium.
3. Stontium.
4. Magnesium.
5. Lithium.
6. Aluminum.
7. Silicum.
8. Glucinum.
9. Yttrium.
10. Zirconium.

3*d*, Those long known by the name of *metals*.

1. Iron.
2. Copper.
3. Lead.
4. Tin.
5. Zinc.
6. Mercury.
7. Antimony.
8. Magnesia.
9. Gold.
10. Silver.
11. Platinum.
12. Rhodium.
13. Iridium.
14. Osmium.
15. Palladium.
16. Bismuth.
17. Cobalt.
18. Nickel.
19. Cadmium.
20. Cerium.
21. Uranium.
22. Chromium.
23. Molybdenum.
24. Tungsten.
25. Tellurium.
26. Titanium.
27. Columbium.

POTASSIUM.

The substance called *potassa*, or *vegetable alkali*, was long considered a simple body, though many conjectures had been thrown out concerning its composition, and numerous attempts made to decompose it. Sir H. Davy, after having discovered the wonderful decomposing power of Galvanism, and having found that substances with similar properties are drawn towards the same pole of a galvanic trough, was led, in 1807, (Ph. Tr.) to try the action of galvanism on potassa, and which was first done with the powerful battery of the Royal Institution of London.

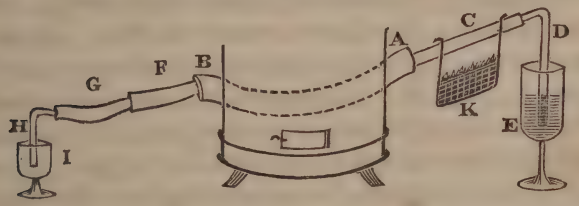
On subjecting its solution to the galvanic action, the water only was decomposed, which suggested the necessity of using the alkali in its dry or fused state, moistening it, as by breathing on it, to make it a conductor. When placed on a platinum cup, connected with the negative end of the trough, and the connecting wire from the positive end made to touch it, it was instantly fused at the points of contact, and there was at the same time an effervescence, and at that part where it touched the cup, very minute globules of a substance resembling mercury in appearance, were observed, some of which soon became covered with a white crust, while others burned with a slight explosion, almost the instant they were formed.

Sir H. Davy had previously established it as a general law, that by the action of galvanism on substances containing oxigen, this elastic fluid is disengaged at the positive wire; he therefore conjectured that it was it that caused the effervescence in the experiment mentioned. He accordingly found, that on collecting the gas, it was pure oxigen. He therefore concluded, that potassa is a compound of it, and an inflammable body. In his first attempts to procure the base, he entirely failed, owing to its being inflamed by the action of air; but by covering the alkali with different fluids, he at last discovered, that distilled oil of petroleum, or naphtha, prevented the combustion; so that he was thus enabled, by subjecting the potass to the galvanic agency under the oil, to procure a sufficient quantity of the inflammable matter, to enable him to ascertain a few of its properties, and to confirm the accuracy of his conclusion, that potassa is a compound of it and oxigen. To the newly discovered body, he gave the name of *potassium*.

By the action of galvanism on potassa, very little potassium can be obtained. Gay Lussac and Thenard have, however, pointed out a method (An. de Chim. lxv.) of procuring it in considerable quantity, which consists in exposing the alkali to iron at a red heat, by which the

iron unites with its oxigen, and is converted to an oxid, while the potassium is set at liberty.

For this purpose, some very clean shavings of iron are put into an iron tube, AB, previously coated with clay and sand, or passed through another tube of earthen ware, to protect it from the fire when brought to a white heat, which is done by passing it through a furnace. An iron bottle, C, filled with potassa, is then attached to the aperture A, and having a small bent tube, D, fitted to its upper end, and made to terminate in a glass of mercury, E. To the aperture of the barrel B, is fixed a



copper tube, F, and again to it a copper receiver, G, both of which are to receive the potassium. To the opposite end of G, is attached a bent tube, H, terminated in mercury, I. When the iron shavings are fully heated, a cage of charcoal, K, is placed under C, to fuse the potassa, and make it pass into the tube, AB, where meeting with the iron, there is at first, owing to the decomposition of the water, a disengagement of hydrogen gas, which escapes at I. When this has begun, the chauffer, K, must be removed, and not again applied till the gas nearly ceases to come off. On repeating the process in this way, there is, each time the chauffer is replaced, a disengagement of hydrogen, but at the same time the potassa is also undergoing decomposition, and coming off in vapour, is condensed in the tubes, FG, which all the time must be kept cool. Should the disengagement of gas at I cease, and gas come out at E, it is owing to the potassium shutting up G; but this is easily removed by holding a chauffer under it, and driving it over into I. When the operation is finished, and the apparatus sufficiently cooled, the tubes FG, are to be re-

moved, and naphtha poured through them, after which the potassium may be taken out, and instantly placed into a phial with naphtha. If any potassium should be lodged in the end of the tube, B, it must be plugged up, and when the furnace is cold, it may be got out by first dipping the tube into naphtha, and then removing it with a wire.

The preparation of potassium is attended with great difficulty, and even when it succeeds, very little of it is procured at a time, and hence the enormous expense of it.

Other methods have also been recommended, by which potassium may be procured much more easily, and in larger quantity, but by no means so pure. By far the best of these, is that recommended by Brunner, and improved by Wohler. It consists in decomposing a salt of potass, as the carbonate by charcoal, in an iron bottle, to which a tube is attached, and made to terminate in naphtha. In this instance, the carbon deprives the alkali of its oxigen, and comes off in the state of carbonic oxid, bringing the potassium along with it, which is condensed in the cool naphtha. For the particulars of the process, *See London Quarterly Journal, No.* xliii.

Potassium has, when recently prepared, the lustre of a metal. It is soft, and can be easily cut, and it then presents the appearance of a piece of newly cut lead. Though resembling metals, it differs from them materially in its specific gravity, being much lighter than water. Gay Lussac and Thenard make it only 865, and Bucholz 876, water being 1000. Its atomic weight, according to Thomson, is 50. It is a good conductor of heat and of electricity. When heated to 70, it becomes semifluid, and about 150 it is quite liquid, and cannot then be distinguished from mercury. Though thus easily fused, it requires nearly a red heat for its volatilization; and if the experiment be performed in close vessels, the vapour is condensed, unchanged in its qualities.

When potassium is exposed to the air, it rapidly acquires a crust on its surface, owing to its uniting with oxigen gas, but in this way it is not completely oxidized,

because the crust formed prevents the farther union of the part beneath it with oxigen.

By heating it in air, and more particularly in oxigen gas, it burns with considerable splendour, and in the last instance, a yellowish matter is formed, which, according to Gay Lussac and Thenard, is a peroxid, which is easily decomposed by water, which drives off part of the oxigen, and leaves the potassium, still retaining so much as to convert it to potassa. When heated in hydrogen, there is combustion, owing to the union of the hydrogen with the excess of oxigen. When heated with carbon, sulphur, or phosphorus, carbonic, sulphuric, or phosphoric acid is formed, which then enters into union with the potassa, and generates a carbonate, sulphate, or phosphate.

The action of potassium and water is remarkable, and presents very striking phenomena. The moment it is touched by it, it takes fire, and burns with a bright red flame. If it be thrown on the surface of a basin of it, it is also kindled, and runs along like a red-hot ball, and there is a slight report when the flame is extinguished. Potassium is even kindled though the water is frozen, for if a small piece of it be thrown on ice, it is inflamed, and makes a cavity, as if the ice were touched by a red-hot wire. In all of these experiments, there is a decomposition of the water, the potassium uniting with the oxigen, to generate potassa, and setting free the hydrogen, which, escaping in the gaseous state, unites with a little of the potassium, and forms an inflammable compound, which is the cause of the particular appearance of the flame. That there is a decomposition and evolution of hydrogen, is shewn by inclosing a small piece of potassium in wire gauze, and thrusting it, by means of pincers, quickly under water, and holding a funneled tube over it; a gas rises which is inflammable, and when exploded with oxigen, generates water. That potassa is formed can be proved, for if cabbage infusion, instead of water, be employed, it becomes green, which, as will be afterwards particularly mentioned, is a distinguishing feature of the alkalies.

These, and the other experiments already mentioned, show the necessity of having potassium excluded from air and moisture, and the care that must be taken, when experimenting with it, not to allow it to be touched by water. The best means of preserving it is to keep it in naphtha.

It is from the ease also with which it acts on water, that it is used for detecting it in other fluids. If, for instance, any of the expensive oils should be adulterated with it, it will easily indicate when this is the case.

By ascertaining the volume of hydrogen evolved by plunging potassium under water, we have an easy method of finding with how much it unites to generate potassa, as it must be exactly half that of the disengaged gas. According to Gay Lussac and Thenard, 100 gr. evolve 116.38 cubic inches, consequently, they must have combined with the half of this, 58.19 inches of oxigen, which weigh 19.72 gr. so that potassa is composed of

potassium,	100.
oxigen,	19.72

According to Berzelius, the proportions are 100 to 20.45, the mean of these is 20.08. So that, considering the atomic weight of potassium as 50, potassa must be a compound of

1 atom potassium,	50
1 atom oxigen,	10
and its atomic weight,	60

The properties of potassium will be afterwards described.

Hydruret.

Potassium unites with hydrogen, and forms a compound called *hydruret of potassium*. When it is heated, by means of a spirit lamp, in the gas confined over mercury, it disappears, and a gaseous compound is

formed, which, when heated in air, burns with a red flame, and potassa and water are the products. It is this that is the cause of the peculiar appearance of the flame of potassium when thrown on water, a little hydruret being formed, which is kindled by the inflammation of the metal.

Phosphuret.—Phosphorus unites with potassium. When they are heated slightly under naphtha, they form a phosphuret, which, when thrown into water, gives off phosphuretted hydrogen, the oxigen uniting with the base; so that potassa is formed.

Sulphuret of potassium may also be obtained in the same way. It is of a greyish colour, and, like many other sulphurets, is decomposed by water, forming sulphuretted hydrogen and potassa, which unite and generate a salt. The sulphuret may also be procured by the decomposition of the compound of potassa and sulphuric acid, by means of charcoal at a red heat, the carbon depriving both the acid and alkali of the oxigen, and leaving the sulphur and potassium to unite. *(See Sulphate of Potassa.)*

Chloruret.—Chlorine acts very easily with potassium. The chloruret may be formed by putting a piece of potassium in a suspended dish into a bottle of the gas, by which there is immediate inflammation and formation of the compound. It is white, like the other compounds already mentioned, and, like them also, is decomposed by water, the hydrogen uniting with the chlorine, and the oxigen with the potassium, so that muriate of potassa is the product.

The chloruret is, according to Davy, composed of

1 atom of chlorine,	45
1 atom of potassium,	50
its atomic weight being	95

Chloruret of potassium may also be formed by putting potassium into muriatic acid, by which the hydrogen is evolved, and the potassium and chlorine unite. It may likewise be obtained by exposing to heat muriate of potassa. *(See Muriate of Potassa.)*

Ioduret.—Iodine also unites with potassium. The union may be effected by heating them together in a glass tube, by which ioduret is formed; and which, like other iodurets, is decomposed by water, and converted into hydriodate.

When potassium is thrown on sulphuric or nitric acid, it is inflamed as when touched by water; indeed, it is by the water in the acid that the combustion is produced.

The only use to which potassium is applied, is as a test of oxigen, as already explained, and as a powerful means of analysis, for which, from its strong affinity for oxigen, it is well adapted.

SODIUM.

After Davy had discovered the compound nature of potassa, he was naturally led to try if the alkali commonly called soda was similarly constituted. By subjecting it to the action of a galvanic battery, the same phenomena were presented,—oxigen gas being given off at one wire, and metallic-looking matter being disengaged at that part of the alkali in contact with the platinum cup. He therefore concluded that it contained oxigen and an inflammable base, to which he gave the name of *Sodium*.

Sodium, in many of its properties, resembles potassium. Its lustre and consistence are nearly the same, but its specific gravity is rather higher; it is 972 water, being 1000. Its atomic weight is 30. It requires a higher temperature for its fusion, not becoming fluid till heated to 194. It is also less volatile.

When exposed to the air it acquires a crust on its surface, and when heated in it, it burns, though with a less bright flame, and requiring a higher temperature for its combustion, than potassium. When heated in oxigen, it forms a peroxid, analogous in its properties to peroxid of potassium.

The action between sodium and water is by no means so remarkable as with potassium; the water is decomposed, but there is no combustion, and a compound of so-

dium and oxigen, called *soda*, is left in solution. The composition of this is found in the same way as that of potassa, by ascertaining the quantity of hydrogen disengaged. According to Davy it is

sodium,	100.
oxigen,	33.33

with which the results of others very nearly agree. And as

100 : 33.33 : : 30 : 10 ;

so that it is a compound of

1 atom of sodium,	30
1 atom of oxigen,	10
its atomic weight being	40

The properties of soda will be afterwards described.

Sodium, at a natural temperature, does not unite with hydrogen,—but at a red heat it can be made to combine with it, and form an inflammable gas.

Sodium unites with phosphorus, sulphur, chlorine, and iodine, the compounds being formed in the same way as those of potassium, and having the same properties, particularly with regard to water, being all decomposed by it, and converted into salts with hydr-acids, with the exception of the phosphuret, in which case the phosphuretted hydrogen is disengaged, and the soda is left in solution.

The only compound of any interest is the *chloruret*, which, during its decomposition by water, becomes the well-known substance *sea salt*, or *muriate* of *soda*. It is composed of an atom of each of its ingredients; that is,

chlorine,	45
sodium,	30
and hence its atomic weight is	75

The other substance generating an alkali, is nitrogen, the properties of which have been already so far detailed. By its union with hydrogen it forms a salifiable base, called *ammonia*, which will be afterwards described.

SECTION VII.

ALKALIES.

The compounds formed by the union of potassium and sodium with oxigen, have been long known by the name of *alkalies;* and they have properties by which they are distinguished from other bodies. They are soluble in water; and their solutions have the power of changing the vegetable blues to green, as is shown by the addition of a few drops to cabbage infusion. Some of the yellow infusions, as that of turmeric, becomes brown. Litmus, which is so delicate a test of the presence of an acid, is not rendered green by alkalies, but is changed to blue; by which, however, as it is itself purple, it answers well as a delicate test; and the best mode of using it is to have it spread on paper, which, when immersed in an alkaline solution, becomes blue.

The oxids of potassium and sodium unite also with the acids, and form a distinct class of compounds, long known by the name of neutral salts.

In addition to the alkalies already mentioned, there is another, similar in its properties, but altogether different in its composition; it is *ammonia*, a compound of nitrogen and hydrogen. Though there can be no doubt with respect to the place it should hold among the salifiable bases, yet, considering the difference in its composition,

it ought not, if we wish to bring substances similarly constituted into the same class, to be brought in with the other alkalies. Nor is it one the compounds of which are in every respect the same as those of potassa and soda; but as there is a great similarity between them, I have thought proper to consider it along with them, though, had I adhered strictly to the arrangement laid down, I ought first to have given the properties of the oxidized bases, and afterwards those of ammonia, as being one with hydrogen. The utility of deviating from this, will, I think, be apparent.

The substances to be considered, then, under this head, are *potassa*, *soda*, and *ammonia*.

Potassa.

Potassa, called also *vegetable alkali*, as generally obtained, is in the form of small cylinders, owing to the figure of the mould in which it is poured when fluid. It is sometimes, also, in small thin plates, having been thrown, when liquid, on a flat table of metal. It is occasionally also, though rarely, got crystallized, the crystals being tetrahedrons or octohedrons, and which contain a large quantity of water. It has a strong disagreeable taste, and is very corrosive. When exposed to heat, it is fused at about 360, and water is expelled. The whole is not, however, driven off, as has been proved by the experiments of Darcet, who concluded, that even after fusion it contains at least 27 per cent.

The experiments of other chemists, however, have shewn that this is overrated. It is now allowed to be about 16 per cent.; and as 16 : 84 : : 11.25 : 59, so nearly 60, that it may be considered a compound of an atom of potass and of water. It is therefore a *hydrate* of potassa. When exposed to the air, it rapidly attracts moisture, and becomes fluid; at the same time, however, it absorbs carbonic acid, so that its properties are complete-

ly changed, and hence the necessity of keeping it in well-stopped phials.

Potassa is very soluble in water, requiring only about half its weight to dissolve it, and during the solution heat is emitted, shewing evidently that there is a considerable condensation, otherwise there must have been a generation of cold, owing to the change of form. The solution is transparent and colourless, and changes vegeble blues to green, or turmeric infusion to brown. By evaporation the potassa can be obtained in its solid form, but not free from water. It has been already mentioned, that even when fused, it still contains 16 per cent. The evaporation of the solution, with the view of procuring the alkali, must be conducted in metallic vessels, such as those of silver or iron, and they should have a cover, with a small aperture to allow the escape of vapour, but prevent the admission of air, and the consequent absorption of carbonic acid, by which the alkali would be destroyed.

The action of potassa with some of the substances already described, as with phosphorus, sulphur, chlorine, iodine, is important, as by it very interesting compounds are formed; besides, the action itself is peculiar, and has given rise to a very important general rule.

When phosphorus is heated with potassa, or when it is brought in contact with it in an incandescent tube, there is an immediate action, and a substance is formed, which, when thrown into water, gives off phosphuretted hydrogen gas. When the potassa in solution is boiled on phosphorus, phosphuretted hydrogen is also evolved, the oxigen uniting with part of the phosphorus, to form phosphoric acid, which remains in the retort, in combination with the potassa, the hydrogen combining with the remainder of the inflammable, to generate the gas which is disengaged. Hence a method of procuring phosphuretted hydrogen; but it is not so good as that in which lime is used, the gas coming off more easily with the latter.

The appearance of the product of the action of potassa with sulphur, varies according to the proportions employ-

ed in its preparation, and different opinions are entertained with respect to its nature. When 1 of sulphur and 3 of potass are mixed, the product becomes warm, and acquires a greenish colour, and a similar substance is formed, when 2 of sulphur and 1 of potass are heated in a covered crucible. These have by some been considered *sulphurets of potassa*, while, according to others, they are compounds of the alkali with acids of sulphur, the water always existing in the potassa having undergone decomposition, giving oxigen and hydrogen to the sulphur to form sulphuric acid and super-sulphuretted hydrogen, both of which are left in union with the alkali. This opinion seems confirmed by the fact, that when a base similar in its properties to potass, but which can be got free from water, is treated in the same way, there is no action between it and the sulphur; but if water is added, a compound resembling that with potassa is formed. Besides, if we consider the above as the action, it is similar to that between potassa and phosphorus; and reasoning from analogy, we should expect them to be the same, for phosphorus and sulphur belong to the same class. The product of the action of sulphur and potassa will be afterwards described. *(See Sulphuretted Hydro-Sulphuret of Potassa.)*

Similar actions take place with chlorine and iodine. When the solution of potass has a stream of the former passed through it, or is heated with the powder of the latter, there is a decomposition of the water, the oxigen uniting with part of the chlorine or iodine, to form chloric or iodic acid, and the hydrogen with the remainder, to generate hydro-chloric, (muriatic,) or hydriodic acid, both of which are left in union with the alkali, forming two different salts, chlorates or iodates, and hydro-chlorates, (muriates,) or hydriodates, and hence a method of forming some of these compounds, particularly chlorates and iodates. *(See Chlorate and Iodate of Potass.)*

From what has now been said of the action of metals and their oxids with the simple bodies just mentioned, two very important general laws may be deduced: 1. When

water is decomposed by phosphorus, sulphur, chlorine, iodine, and *a metal*, that is, by phosphurets, sulphurets, chlorurets, and iodurets, the oxigen unites with the metal, the hydrogen with the other body. 2. When water is decomposed by phosphorus, sulphur, chlorine, iodine, and a *metallic oxid*, both the oxigen and hydrogen unite with the phosphorus, sulphur, chlorine, or iodine.

In the first instance, with the exception of phosphurets, we have hydr-acid salts formed, as hydro-sulphurets, hydro-chlorates, and hydriodates. In the latter also, with the exception of phosphorus, there are both oxi-acid and hydr-acid salts generated. In the case of phosphorus, the compound of it and hydrogen not being an acid, it does not unite with the alkali, but this does not in the least affect the general rules, in so far as the action on the water and the other bodies is concerned.

By the union of potassa with the acids already described, a class of compounds called *neutral salts* is formed, the properties of which will be afterwards given.

Potassa is no where found in its pure state. It exists, however, in many minerals, combined with other bodies, and also in vegetables, from which it is generally procured by burning them, and dissolving the ashes. As thus obtained, however, it is in the state of carbonate, from which the carbonic acid is removed by lime. *(See Carbonate of Potassa and Lime.)*

Potassa, owing to its powerful affinity for water, is employed for rendering gases dry, for which purpose the gas, confined over mercury, has a few pieces of alkali put into it, where it is allowed to remain for some hours. In solution, potassa is used in soap-making, in bleaching, and in the manufacture of glass. *(See Oils, Lime, Silica.)*

Soda.

Soda, or the *mineral alkali*, as it is sometimes called, was long mistaken for potassa. Duhamel, in 1736, first pointed out the difference between them, which is not so

much in the properties of the alkalies themselves, as in those of their compounds.

In its appearance, taste, action with air and with water, it is similar to potassa. When fused, it contains about 22½ per cent. of water, or an atom of water and of alkali.

The action of phosphorus, sulphur, chlorine, and iodine, with soda, is the same as with potassa, the water undergoing decomposition, giving both of its ingredients to the phosphorus, sulphur, chlorine, and iodine, and in the last three cases forming acids which combine with the soda.

Soda, by its union with the acids, forms salts, and it is in the properties of these that the distinction between it and potassa is observed.

Soda is not found in its native state. It exists in combination in some minerals; but by far its most productive source is sea salt, in which it exists in union with muriatic acid. In rock salt also it is in a similar state of combination, and from both of these it is procured. *(See Sea Salt, Kelp, Barilla.)*

Soda is used for the same purposes as potass; indeed it is in general preferred, particularly in soap-making.

Ammonia.

The two alkalies already described are compounds of metallic bases and oxigen, but ammonia is altogether different in its composition, being, as will be immediately proved, a compound of hydrogen and nitrogen.

Ammonia, *volatile alkali*, or *hartshorn*, is distinguished from the preceding by its volatility; indeed, at a natural temperature, when pure, it is always in the gaseous form. Though the alchemists were acquainted with it in a state of solution, it was not discovered in the form of gas till the time of Priestley, who gave it the name of *alkaline air*.

It is a transparent and colourless gas, possessing the usual mechanical properties of aeriform fluids. It has a pungent irritating odour. Its sp. gr. according to the

experiments of Gay Lussac, is 596; and 100 cubic inches weigh 18.17 gr. It is unfit for the support of respiration and combustion. When subjected to strong pressure, or to a cold of —56, it lays aside the gaseous form, and becomes a colourless fluid, which evaporates at 60, even though kept under the pressure by which it was condensed.

When subjected to a high temperature, it is decomposed, and resolved into its component parts, hydrogen and nitrogen. This is easily effected by putting the solution of the alkali in water, into a retort, *(Cut, p. 138.)* to which an earthenware tube is attached, and passed through a chauffer to bring it to a red heat, the opposite end of the tube being made to terminate in a water trough. On applying a slight heat to the retort, the ammonia is expelled, and passing through the tube, it gives off a gaseous matter, which may be collected in the jar. It is evident that this is not the watery vapour from the solution, otherwise it would have been condensed the moment it came in contact with the fluid in the trough. That it contains hydrogen, is shewn by its inflammability, and during its combustion generating water. Or if it be mixed with oxigen, and an electric spark passed through it, it explodes, water is formed, and a gas is left which does not support combustion, and does not render lime-water turbid, and is therefore nitrogen.

Ammonia is also resolved into its component parts by means of electricity. When the gas is put into a tube over mercury, and electric sparks are for some time passed through it, it gradually enlarges, till at last it becomes of double its original bulk, after which there is no farther enlargement. On firing the product with oxigen by electricity, $\frac{3}{4}$ are found to be hydrogen, the remaining $\frac{1}{4}$ nitrogen. It has been proved also by Henry, that if ammonia gas be fired repeatedly with small quantities of oxigen, water and nitrogen are the result.

It has been attempted, but without success, to

cause hydrogen and nitrogen to unite to form ammonia, so as to prove its composition synthetically. If, however, they be presented to each other, when one or both is nascent, ammonia is formed, as has been proved by the experiments of Dr Austin. He found that, when a jar of nitrogen was kept over mercury, having moistened iron filings on its surface, ammonia was formed, the oxigen of the fluid having combined with iron, and set free hydrogen, which must, when nascent, have united with the nitrogen. Again, if tin be put into much diluted nitric acid, it takes oxigen both from the acid and water, so that there is a gradual disengagement of hydrogen from the latter, and of nitrogen from the former, which uniting, generate ammonia, but as it is left in union with part of the acid, it is necessary to add lime, by which it is liberated, evincing itself by its smell. All of these experiments prove that hydrogen and nitrogen are its ingredients, and the decomposition by electricity, shews that it contains 1 of nitrogen, and 3 of hydrogen, condensed into 2. If so, the proportions by weight must be

sp. gr. of hyd. $\times$ 3 = 208 + sp. gr. of nitr. 972 ;

and as 972 : 208 : : 17.5 : 3.71,

and $\frac{3.71}{3} = 1.23$;

so that we may consider it a compound of

1 atom of nitrogen,	17.5
3 atoms of hydrogen,	3.75
its atomic weight being	21.25

Its compositions may also be stated to be

	Vols.		Vols.
nitrogen,	1	} condensed into	2 ;
hydrogen,	3		

and if so, its specific gravity must be

$$\frac{972 + (69 \times 3)}{2} = 590,$$

the number given by Thomson.

After Davy had discovered the compound nature of

potassa and soda, he was led by analogy to infer, that, like them, ammonia might contain a metallic substance as one of its ingredients. It was found that when mercury, in contact with ammonia, was subjected to the influence of galvanism, it enlarged, and became of a thickish consistence, but it still retained its metallic lustre; and the same results were obtained by using an ammoniacal salt instead of the pure alkali. When also potassium and mercury were placed on a salt of ammonia, and touched with water, similar appearances were presented, the mercury becoming several times its original volume, and of the consistence of butter. These changes are the same as those effected on mercury by another metal, and hence it was supposed that it had acquired a metallic matter from the ammonia. When the amalgam was exposed to air, or put into water, ammonia was produced, in the former instance oxigen being absorbed, and in the latter hydrogen disengaged, the metallic base supposed to be in union with the mercury, having, it was imagined, united with oxigen, either from the air or from the water, to produce the alkali. These experiments have induced some to imagine that ammonia is a compound of a metallic base and oxigen, and therefore similar in its constitution to potassa and soda; but Gay Lussac and Thenard have given a different view of the subject. They suppose that the amalgam is a compound of mercury, ammonia, and hydrogen, the last derived from the decomposition of the water with which the salt is touched to cause the action to go on; hence, when exposed to air, or put into water, there is the evolution of ammonia and of hydrogen, the ammonia in the latter case being left in union with the fluid.

Though chemists are as yet undecided with respect to the nature of the amalgam, there can be no doubt, from what has been already said, that ammonia is composed of hydrogen and of nitrogen; so that, if it does contain a metallic base, it must exist as an ingredient of one or both of these; but all attempts to procure it in its separate state have failed.

Ammonia has a powerful affinity for water, being absorbed by it with great avidity. If, for instance, the stopper of a tall bottle full of it be withdrawn under water, the fluid is thrown up with great rapidity, or if a few drops of water be admitted into a jar of it, standing over mercury, there is an immediate absorption, and the fluid thus becomes saturated with the gas. The solution formed is transparent and colourless, has a sharp pungent taste, and is very stimulant to the animal frame. It has the odour of the gas, and changes vegetable blues to green. Hence, if, in the experiments just mentioned, cabbage infusion, instead of pure water, be employed, the fluid, as it flows into the bottle, becomes green.

At 50, according to Davy, water takes up 670 times its bulk of gas, the sp. gr. becoming 875, while, according to Thomson, the quantity absorbed is not less than 780. The solution congeals at —58, and by the application of heat, gives off the whole of its gas, and hence a method of procuring it, though it is not one that is much practised, as it comes off loaded with moisture. If it is wished to prepare it in this way, all that is necessary is to put a little of the solution into a retort, apply the heat of a spirit lamp, and collect the gas over mercury. If, after procuring it, it is required free from moisture, we have merely to put in a few pieces of potassa or lime, and leave them for some time.

The solution of ammonia also loses its alkali by exposure to air, the greater part of it flying off, and hence the necessity of keeping it in well-stopped phials.

Ammonia is peculiar in its actions with some of the simple bodies already described. When, for instance, a bottle of chlorine gas is placed on one full of ammonia, there is an immediate condensation, accompanied with the evolution of heat and light, and the formation of a white powder, a compound of ammonia and muriatic acid. In this instance, there is a decomposition of part of the ammonia, the hydrogen of which unites with the chlorine to form muriatic acid, setting the nitrogen at liberty. The acid thus formed then enters into union with the re-

mainder of the alkali, and produces the salt called muriate of ammonia. The proper proportions for the experiment are, 1 of ammonia to 3 of chlorine. With the aqueous solution of ammonia, however, the action is different. When chlorine is exposed to it, the whole of the alkali is decomposed, both of its ingredients uniting with it, forming muriatic acid and chlorid of nitrogen, and hence a method of preparing the latter, though it is seldom practised, a solution of an ammoniacal salt answering better. (*See p.* 262.)

The action with iodine is exactly the same, when a little of it is thrown into solution of ammonia, iodid of nitrogen is produced, and hence the method by which this is prepared. (*See p.* 272.)

Ammonia unites with the acids, and forms *neutral salts*, with the exception of those having carbonic acid, the compounds with it still retaining alkaline properties.

Ammonia is not found any where in a state of purity. It has been detected in some varieties of lava, and also in basaltic rock, from which it may be procured by distillation. Ammonia, or rather the compounds into which it enters, are generally attained by the decomposition of animal matter, which, besides it elements hydrogen and nitrogen, contains also carbon and oxigen. This is done merely by subjecting it to a strong heat in retorts, by which the hydrogen and nitrogen unite to form ammonia, while the hydrogen and oxigen, and oxigen and carbon, form water and carbonic acid, and by causing the ammoniacal gas, as it comes off, to meet with acid vapours, they unite and form compound salts, and it is by the decomposition of these, chiefly by lime, that ammonia in a state of purity is procured. *(See Muriate of Ammonia and Lime.)*

Ammonia is used in medicine, in the state of solution; internally as a stimulant, externally either alone or in union with oils, as a rubefacient. It is administered also in the gaseous form, in cases of syncope, as a stimulant to the olfactory nerves.

SECTION VIII.

ALKALINE SALTS.

Nitrates.

Nitrate of Potassa.

Nitrate of Potassa, commonly called *nitre* or *saltpetre*, is generally obtained in the form of six-sided prismatic crystals, terminated by six-sided pyramids, but it is occasionally in dodecahedrons, or two six-sided pyramids, joined by their bases, the specific gravity of which is 1933.

Different statements have been given of its composition, but later experimenters agree that it is composed of about

nitric acid,	53.5
potassa,	46.5

So that it does not contain any water of crystallization, though there is occasionally a little present, but this is extraneous, and must be considered as merely blended with the particles, having been taken along with them during their deposition from solution.

Now as 53.5 : 46.5 : : 67.5 : 58.6

so nearly 60, that we may consider it composed of

1 atom acid,	67.5
1 atom potassa,	60.
its atomic weight being	127.5

Nitre is easily fused by heat, and becomes a transparent limpid fluid; which, if the high temperature be continued, gives off a gaseous substance, composed of oxigen and nitrogen, but with the former in largest proportion; indeed, so much so, that it may be used for many of the purposes to which oxigen gas is applied. An ounce of salt yields from 700 to 800 cubic inches. There remains in the crucible the potassa, but with deficiency of acid, so that the elastic fluid is formed by the decomposition of part of it.

Nitre is soluble in water, requiring about 7 parts at 60, but at a boiling heat only its own weight, for solution; and from this, as the temperature falls, crystals may be obtained. During the solution there is a generation of cold; and hence the frequent use of nitre, particularly in India, for reducing the temperature of bodies, as wine,—and in the preparation of ice, as in cooling the water which is to be exposed during evening, in the porous earthenware dishes.

Nitre acts very powerfully with inflammables, the action being peculiar, and attended with particular phenomena. When charcoal, or sulphur, is thrown into it, previously melted in a crucible, it burns with great splendour, accompanied occasionally with slight explosions. This is called *deflagration.* The rapidity of the combustion depends on the ease with which the nitre parts with its oxigen to the inflammable; of course, the product differs according to the substance presented to it; but in all, the inflammable is acidified, by its uniting with the oxigen of the nitric acid, which is thus destroyed, while that acid formed is left in combination with the potassa. Thus, when pieces of charcoal are thrown into melted nitre, the latter is converted to carbonate of potass, or if sulphur be employed, sulphate of potassa is the product. When nitre is more intimately blended with the inflammables, the combustion is more rapid, and, if effected in a close vessel, is accompanied with explosion, the loudness of which depends on the quantity of the

mixture, and the vessel in which it is exploded. From this property of nitre, it is employed in the preparation of signal-lights and matches, and it is also one of the ingredients of gunpowder.

The discoverer of gunpowder is not known. It is mentioned in the works of an author who wrote in the latter part of the 13th century, and it appears to have been used in the beginning of the 14th by EDWARD III. in his first attack against the Scots in 1327. It was also employed at the siege of Calais in 1346.

The materials used in its preparation are, nitre, charcoal, and sulphur, the proportions of which vary in different places. In general, they are about 75 of nitre, 15 of sulphur, and 10 of charcoal. These must be all quite pure, otherwise the strength of the powder is diminished; accordingly, the nitre is always purified by solution and crystallization. For this purpose, it is dissolved in boiling water, and poured into large copper vessels, in which it deposits crystals. These are again dissolved and crystallized, and even in some cases the process is repeated a third time, by which the whole of the impurities are removed, and which impart to it deliquescent properties, or the power of absorbing moisture from air. After this, it is fused in iron pots, so as to drive off any adhering moisture. The sulphur employed is generally that brought from Italy and Sicily. It is also purified, by fusing it, and allowing it to cool gradually, by which the earthy impurities fall to the bottom. From this, when solid, it is removed, and sometimes again submitted to a similar process. The charcoal is prepared by subjecting wood to a strong heat in cast-iron cylinders, in which it remains till it becomes cold, and it is in general kept in boxes till required. The lighter woods are usually preferred, such as alder and dogwood, and they are always freed of the bark before being charred.

The ingredients are first ground to powder separately, and then mixed in the proportions mentioned, after which

they are more intimately blended, by means of iron rollers, the mixture being kept constantly moist, to prevent explosion, and the quantity not exceeding about 50 pounds under each roller. After the materials are properly incorporated, the mixture is subjected to the process of *corning*, by which it is reduced to grains. This is done by pressing the paste into small pieces, which are placed in circular boxes, with parchment bottoms, perforated with holes of different sizes, according to the required size of the grains, and in which, also, there is a block of hard wood. These are connected with a wheel, by which they are moved in a horizontal direction, and, by the action of the block, the paste is reduced to grains, and passes through into boxes placed beneath for their reception. After this they are *glazed*, by putting them into barrels, revolved by machinery, in which, by the constant friction against each other, their surface is hardened, and they acquire a fine gloss, which, though it diminishes a little the strength of the powder, yet renders it less liable to be injured by moisture. The next part of the process is the *drying*, which is done in different ways in different manufactories. In general, the powder is placed on shelves, in a small brick house, through which there passes the vent of a furnace, or into which a cylinder of iron projects, kept constantly red hot by means of a fire without the building. A method of drying gunpowder by steam has been lately practised, in which there is no danger whatever, as the temperature in this way cannot go beyond 212, *(See page* 81.*)*; but it is said not to dry it so uniformly as the other, and is therefore not much practised. It consists merely in placing the powder on boxes, kept constantly full of steam, the condensed vapour escaping from the box, by a tube terminating without the building. After the whole of the moisture is expelled, the powder is put into casks, keeping it as much as possible excluded from the air, particularly if moist, for when much exposed, it absorbs moisture; and as the nitre is the only soluble ingredient, a

part of it is thus apt to be removed, by which the powder is destroyed.

In the preparation of gunpowder, the more minutely the materials are ground, and the more intimately they are mixed, the greater is the explosive power of the powder. The strength also depends in a great measure on the drying; for when too much heat has been applied, part of the sulphur is driven off; besides, a hard crust is formed on the surface, which prevents the moisture escaping from the inner parts. When well prepared, the powder, when exploded on a piece of paper, ought to leave little or no residuum, the whole of the ingredients entering into a new state of combination, and generating products, which are given off in the form of gas. If any particles remain on the paper, it shews either that the ingredients have not been pure, or not in proper proportion.

When gunpowder is heated, the action is owing to the ease with which the nitre parts with oxigen to the inflammables, the sulphur and carbon combining with it to form carbonic, and sulphuric or sulphurous acids, while the acid of the nitre, by losing part of its oxigen, forms nitric oxid, the generation of all of which is the cause of the explosion; at the same time, the water in the powder undergoing decomposition, affords hydrogen to part of the sulphur, and generates sulphuretted hydrogen, which gives rise to the offensive smell. That a large quantity of aeriform matter is given off by gunpowder, is easily shewn, by putting a little of it moistened into a tin tube, kindling it, and then plunging it quickly under the mouth of a jar, inverted on a water trough, keeping the mouth of the tube down. As the powder is moistened, it does not explode, but is slowly consumed, and gas arises into the jar, which, when cold, occupies about 250 times the volume of the powder itself; but the heat evolved during the action is supposed to expand it to 1000; and as each volume exerts the same pressure as the atmosphere, 15 pounds on the square inch, we have thus the pressure

of 1000 atmospheres, so that its expansive force is 15,000 pounds, by which a ball is propelled from a gun with a velocity of about 2000 feet in a second. The strength of different kinds of powder varies, however, considerably, and hence it is that each sample is tried before it is purchased by government; which is done by ascertaining the distance to which it sends a ball, using the same gun, similar balls, and the same weight of powder, in all the trials.

Nitrate of potassa is also employed in the preparation of signal-lights and matches. The portfire of artillerymen is a mixture of 60 of nitre, 40 of sulphur, and 20 of gunpowder, the materials being made into a paste, and stuffed into cylinders of paper. Signal lights are mixtures of nitre and sulphur, with a little metallic matter, that communicates to the flame a peculiar colour. The white light is composed of 6 of nitre, and 2 of sulphur, to which is added 1 of orpiment, or yellow arsenic; and the blue light consists of the same proportions of nitre and sulphur, with 2 of crude antimony.

The action between nitre and some of the acids, particularly sulphuric, is important, as by it we can decompose it and procure its acid, the affinity between the alkali and the sulphuric being more powerful than that between it and the one with which it is united. Hence the mode of preparing both nitrous and nitric acid, the first of which is usually procured by the decomposition of the nitre, and from it the latter can be easily obtained.

Different proportions of acid and nitre have been recommended, with the view of procuring nitrous acid. Those given by the Edinburgh Pharmacopœia are,

Nitrate of potass, bruised, two pounds;
Sulphuric acid, sixteen ounces.

Having put the nitre into a retort, and adapted a receiver, which must be kept open and cooled in the usual way, heat is to be applied, and continued as long as acid fumes come over; after which, having removed the heat, the retort is to be allowed to cool gradually, to prevent it

from cracking. What remains in it is the compound formed by the union of the sulphuric acid and potassa, and, as it is but sparingly soluble, it requires to have warm water poured on it repeatedly, and left on several days each time, so as to wash it out.

The colour of the acid in the receiver depends in a great measure on the heat; that which comes first over being pale yellow, and of great specific gravity, but it gradually becomes darker and of less density as the distillation proceeds; the specific gravity of the product is in general 1520.

The above is the method of conducting the process on a small scale. If larger apparatus be used, it is necessary to apply the heat through the medium of a furnace and sand-bath, keeping the receiver cool by a stream of water from a cistern, from which there hang some worsted threads to draw it off, drop by drop.

In the decomposition of nitre by oil of vitriol, the sulphuric acid unites with the potassa, while the nitric acid is disengaged, but at the same time, probably owing to the high temperature at which the action is going on, is decomposed, a part of its oxigen being expelled, and it is thus converted to nitrous acid, which is condensed in the receiver along with the water of the oil of vitriol; the oxigen escapes in the gaseous form, and hence the necessity of keeping the mouth of the receiver loosely adapted to the neck of the retort. If, instead of a common receiver, a tubulated one be employed, and the tube carried under a jar in a water trough, the elastic fluid may be collected, and is found to be pure oxigen.

The acid thus obtained by the decomposition of nitre is not pure nitrous acid, it almost always contains a little muriatic and sulphuric acid; the former derived from sea-salt existing in the nitre, the latter from part of the oil of vitriol being distilled over. It is sufficiently pure, however, for most purposes, but when required free from foreign admixture, the nitre ought to be purified

by repeated crystallization, and the acid obtained must be redistilled along with a little of the compound called nitrate of lead, the metal of which retains the foreign acids, and allows the nitrous acid to come off pure.

It has been mentioned, that the colour of the product depends, in a great measure, on the temperature and proportions employed. It must not, however, from this be supposed that there is a variety of nitrous acids; the difference in the colour is occasioned by an admixture of nitric acid which has escaped decomposition, and which, being colourless, the more there is of it, the colour of the nitrous acid becomes paler.

Nitrous acid, as thus obtained, is easily decomposed by heat, and converted to nitric acid; and hence a method of procuring it. For this purpose any quantity of nitrous acid is put into a retort, (using the same apparatus as in the former experiment,) and a very slight heat applied, which must be kept up till the liquid becomes colourless. In this process, the acid is gradually decomposed; nitric oxid being disengaged, and nitric acid left in the retort, so that one part must deprive the other of oxigen, that gaining it becoming nitric acid; the other, which has lost it, nitric oxid. The gas, liberated instantly, unites with the oxigen of the air in the apparatus, and forms nitrous acid, which is condensed in the receiver; and hence the necessity of keeping it cool, and having the mouth open to admit atmospheric air.

If a larger proportion of oil of vitriol than that ordered in the Edinburgh Pharmacopœia be employed, the acid is paler; indeed, so much so, that by the London College it is called *nitric;* and hence the process ordered by them for procuring this acid, which consists in employing equal weights of oil of vitriol and nitre; and the reason for using this excess of acid is, that a sufficient quantity of water be afforded to the nitric acid that comes off.

Nitrate of potass consists of

1 atom of nitric acid 67.5
1 atom of potass 60 } = 127.5;

oil of vitriol consists of

1 atom of sulph. acid 50
1 atom of water 11.25 } = 61.25;

but 1 atom of nitric acid
requires 2 atoms of water
to form 1 atom of liquid acid;

so that unless 2 atoms of oil of vitriol (= 122.5) have been employed, the whole of it cannot be disengaged from the nitre, and consequently all the salt is not decomposed. From this it is evident that, using the proportions ordered by the London College, the products, provided there is no decomposition of the nitric acid itself, should be

1 atom nitric acid 67.5
2 atoms water 22.5 } = 1 atom liquid acid 90

1 atom potassa 60
2 atoms sulph. acid 100 } = 1 atom bisulphate of potassa 160

It is almost impossible, however, to get the nitric acid off without decomposing part of it, and hence it is that it is always coloured from the presence of nitrous acid, and by which there is, of course, a loss; but this is much less than when the process of the Edinburgh Pharmacopœia is followed, for, from the small quantity of oil of vitriol used, the whole of the nitre is not decomposed; but this, it is supposed, is compensated by the residue in the retort being more easily washed out, and by there being less risk of any of the sulphuric coming over with the nitric acid. Of course, in this process, bisulphate of potass is also formed, for each atom of nitric acid set free must have 2 of water, and by which 2 of sulphuric acid are to unite with the potassa disengaged from the nitre.

It has been already mentioned, (*see p.* 292.) that nitrous acid fumes are employed with great efficacy in disarming contagious effluvia of their virulence; and hence their use in purifying apartments in which sick have been

confined, and in preventing contagion. The ease with which nitre is decomposed by sulphuric acid, affords a means for procuring the acid vapour. For this purpose, a little oil of vitriol is placed in a tea-cup, which is to be heated in a ladle with sand, taking care not to raise the temperature so far as to make it give off fumes. Some nitre is then to be thrown in, by which the sulphuric acid unites with the potassa, and the nitrous acid vapour is disengaged. If the room is large, several cups may be placed in different parts of it, or the ladle may be carried from one part to another.

Nitrate of potass is not decomposed by any of the other acids.

Nitre is a native production. It is found in the stems of some plants, as tobacco. It exists also in several minerals, and in the soil of some countries, as Hungary, Spain, South America, East Indies, and China, from which it is obtained by lixiviation and evaporation, affording what is called *rough nitre*, from which it is obtained pure by solution and crystallization.

Nitre, as has been already explained, is used in the preparation of gunpowder, signal lights, and nitrous and nitric acids. It is employed, also, in the manufacture of oil of vitriol.

When sulphur burns slowly in air, sulphurous acid is formed; but when it is mixed with a little nitre, the combustion is more lively, and sulphuric acid is the product. To obtain the acid from this mixture, large leaden chambers are built, having two openings, one a door at a few inches from the bottom, for the introduction of the mixture, the other, also near the bottom, furnished with a stop-cock, through which the acid is drawn off. Water is poured in to the depth of about two or three inches, and the mixture of sulphur and nitre, in the proportion of about 8 or 10 of the former to 1 of the latter, contained in an earthen pot, is placed on a stand in the chamber, and then kindled. When the combustion has ceased, more is put in, and in this way it is carried on for some

weeks, at the end of which the fluid is drawn off into large retorts of glass or platinum, and concentrated by evaporation, till it becomes of the proper strength,—specific gravity 1847. It is then poured into large green bottles, called *carboys*, surrounded by basket-work, in which state it is sent to market.

Sulphuric acid prepared in this way always contains a little lead, derived from its acting on the walls of the chambers, but from which it is easily freed by mixing it with an equal quantity of water, by which a white powder falls as the mixture becomes cold. This is the lead, in union with a little of the acid, from which the clear fluid is poured off, and, if required strong, must be concentrated by evaporation.

It was at one time supposed, that the nitre operated in this instance by affording oxigen directly to the sulphur, to form sulphuric acid; but this is now known not to be the case, for if the acid vapour be collected the moment it is generated, it is not sulphuric but sulphurous acid; besides, there is not nearly enough of nitre to supply oxigen for the complete acidification of the sulphur. Clement and Desormes have given a different explanation of the action. They imagine, that when the sulphur is inflamed, it forms sulphurous acid, by taking oxigen not only from the air, but also from the nitric acid, by the decomposition of the last of which, nitric oxid is generated. The moment this comes off, meeting with atmospheric air, it unites with its oxigen, and generates nitrous acid, which instantly gives off oxigen to the sulphurous, to convert it to sulphuric acid, and be reduced itself again to the state of oxid, again to be ready to take more oxigen to form nitrous acid, which is to communicate oxigen to the next portion of sulphurous acid formed by the combustion of the sulphur; so that the sulphur acquires as much as will convert it to sulphuric acid, not from the nitric acid of the nitre, but from the air, through the intervention of the nitric oxid; consequently, there is no necessity for a large quantity of nitre, because the oxid generated from it, after it has

united with oxigen, is, by giving this off to the sulphurous acid, brought to the same state as before, and is ready to deprive the air of more, to communicate it to the next portion of sulphurous acid formed.

Nitrate of Soda.

Nitric acid unites with soda, and forms a neutral compound, the properties of which are similar to those of nitrate of potassa, but it has been very little examined, and it is not put to any particular use. It has been lately found in large quantity in Tarapacca in Peru, and there are also lakes in Hungary which yield it in considerable abundance.

Nitrate of Ammonia.

Nitrate of ammonia is obtained in different forms, either in the state of a compact salt, or in prismatic or fibrous crystals, according to the mode by which it has been prepared. It has a cooling, bitter taste; is deliquescent and soluble, requiring about 2 of water at a natural temperature, and half its weight at a boiling heat, for solution, and from which crystals are deposited as it cools. The quantity of water in the salt varies according to its form. Davy states that there is

in the prismatic crystals,		12 per cent.
fibrous	do. -	8 —
compact salt,	-	5.7 —

But as usually purchased, it in general has no less than 20 per cent. probably owing to deliquescence.

The composition of the different salts is, according to Davy,

	Prismatic.	Fibrous.	Compact.
acid	69.5	72.5	74.5
base	18.4	19.3	19.8
water	12.1	8.2	5.7

Berzelius states the first to be composed of

acid 67.62, base 21.14, water 11.24.

Now these numbers are very nearly the atomic weights of each; so that we may consider it composed of

1 atom acid, -	67.5
1 atom ammonia, -	21.25
I atom water, -	11.25
and its atomic weight,	100.

By far the most important action of nitrate of ammonia is with heat, by which it is decomposed, and yields nitrous oxid, and hence its use in the preparation of this gas. For this purpose, any quantity is put into a retort, and heated by means of a lamp or chauffer, by which it at first undergoes watery fusion; but on continuing the heat, the whole of the water is expelled, and the salt itself is fused, and then begins to suffer decomposition, the whole of the hydrogen of the ammonia uniting with as much oxigen from the acid as to generate water, while the remaining ingredients, that is, the rest of the oxigen and the nitrogen of both, combine and form the oxid, which comes off with the watery vapour, and may be collected over a water-trough, the vapour being condensed by the cold.

In this experiment, each atom of salt must yield 2 atoms of oxid; for 1 of nitrate consists of

1 atom of acid = { nitrogen 1, oxigen 5 }

1 atom of ammonia = { nitrogen 1, hydrogen 3 }

Water and nitrous oxid, the only products of the action, contain 1 atom of each of their ingredients, so that

{ hydrogen 3, oxigen 3 } = water 3

{ nitrogen 2, oxigen 2 } = nitrous oxid 2

The different salts require different temperatures for their decomposition; it is, however, in all below 500, and in the preparation of the oxid, it should not be allowed to go beyond this, because nitric oxid is apt to be formed. A pound of good salt will yield about 5 cubic

feet of gas; and as about 1-6th of a foot is sufficient in general for producing its effects when breathed, about 1-3d of an ounce should yield enough for one individual. In preparing the gas with the view of respiring it, before beginning to collect it, it must be tried from time to time, with a piece of wood recently extinguished; if it kindles it, it may be considered pure; and it ought also to be allowed to remain over the water for about half an hour, to deprive it of a little of the salt which it frequently holds in suspension; or it may be shaken with the water for a minute or two, which will completely purify it. It is necessary, also, to try whether it contains any nitric oxid, and which is done by the introduction of a few bubbles of air. If red fumes appear, the oxid is easily removed, by adding air, or oxigen, till the fumes cease to be formed.

Nitrate of ammonia is acted on by inflammables in the same way as nitre, undergoing deflagration by affording them oxigen; and it is decomposed also by oil of vitriol, but it is not put to any particular use in this way.

It is prepared by the addition of the acid to the salt called carbonate of ammonia, by which the carbonic acid is expelled, and the nitric acid and ammonia unite, and may be obtained in the state of nitrate by evaporation.

Carbonates.

Carbonic acid unites in two proportions with the alkalies, and forms salts, not however differing much in their properties. The one is called *carbonate*, the other *bi-carbonate*, which are a very interesting class of bodies, as from them many of the other salts are formed, and they are used also in several important operations of the arts.

The salts formed by the union of alkalies and carbonic acid, possess many of the properties of the former. They retain, to a certain extent, their taste, and those with ammonia have also its odour. They change vegetable blues to green, and they effervesce on the addition of

any acid, owing to the disengagement of their carbonic acid.

Before the discoveries of Dr Black respecting carbonic acid, the carbonates were considered to be the alkalies in their pure state. It was known, that when any of them was mixed with lime, it lost its mildness, and became caustic, which was supposed to be owing to its having acquired something from the earth. Dr Black however shewed, that what was considered the pure alkali contained carbonic acid, which, by the admixture with lime, was transferred to it, and the alkali then became pure.

Carbonate of Potassa.

This is the salt long known by the name of *Potashes*, *Pearl Ashes*, and *Salt of Tartar;* but in these it is not pure, being mixed with other salts and siliceous matter. If a bottle of carbonic acid gas have a little solution of potassa thrown into it, and after corking it they be shaken together, keeping the mouth down, the gas is quickly absorbed by the alkali, and the air enters through the pores of the cork to supply its place. Though the alkaline carbonate may be thus obtained, it is never prepared in this way for use, being procured in large quantity by the combustion of vegetable matter.

As usually purchased, it is in the form of a white granular powder, or in coarse pieces. It has an acrid taste, is powerfully absorbent of moisture, and is therefore *deliquescent;* so that, when exposed to the air for some time, it absorbs a sufficient quantity to make it become fluid.

It is soluble in water, requiring about its own weight at 60 to dissolve it. The solution is transparent and colourless, and changes vegetable blues to green, shewing that there is not enough of acid to saturate the alkali; so that it is not, strictly speaking, a neutral salt.

The composition of this salt, as given by Wollaston, is,

carbonic acid, 100.
potassa, 218.8
and as 100 : 218.8 : : 27.5 : 60.

So that it contains

1 atom of acid,	-	27.5
1 atom of potassa,	-	60.
its atom being	-	87.5

Carbonate of potass acts with some of the simple substances already described, as chlorine and sulphur, and the action is the same as that already mentioned with potassa, *(see p. 375.)* the water in the salt undergoing decomposition, and affording oxigen and hydrogen to the other substance to generate acids. In this way, by fusing sulphur with the alkaline carbonate, the substance commonly called *sulphuret of potass* is formed, but which is a mixture of salts with acids of sulphur. *(See Sulphuretted Hydro-Sulphuret of Potass.)*

The same action takes place with chlorine and iodine, when the potass is in solution, chlorate and muriate, or iodate and hydr-iodate of potass being formed by the chlorine and iodine gaining oxigen and hydrogen from the water. *(See Chlorate and Iodate of Potass.)*

Carbonate of potass is easily decomposed by the acids, which combine with its alkali, and disengage its acid with effervescence, the decomposition being effected by using either the dry salt, or its solution. Though this salt yields carbonic acid easily, it does not answer for affording it, because the action is by far too rapid.

Carbonate of potassa is prepared by the combustion of vegetables, more particularly in those countries which abound in wood, as in America and Russia. For this purpose, the ashes collected from the wood used as fuel are washed with water, and the solution, after filtration, evaporated to dryness. What is left is the carbonate, though in an impure state, as it contains vegetable matter, and some other salts; but it is sufficiently pure for the uses to which it is generally applied.

Vegetables always contain potassa, probably in combination with a vegetable acid; hence, by the combustion, the carbon in them combines with the oxigen of the air, and forms carbonic acid, which then enters into union

with the alkali, previously deprived of its acid by the combustion. It is obtained in different quantities from different vegetables. Herbaceous plants yield most, next the shrubs, and least of all the trees. Even the various parts of the same plant afford it differently; thus, the leaves give more than the stems or trunks. Hence the *potashes* and *pearl ashes* of commerce, contain different quantities of pure alkali; and as it is for this they are prized, it is of the utmost consequence that we should be able, by an easy method, to ascertain its proportion. *(See Appendix.)*

Carbonate of potass is employed in bleaching, and in the manufacture of glass and soap; it is likewise used for yielding pure potassa, by decomposing it by means of lime. *(See Lime, Silica, Oils.)*

Bi-Carbonate of Potassa.

When a stream of carbonic acid gas is passed through a solution of carbonate of potass, it is absorbed, and a bi-carbonate is formed, having of course double the quantity of acid. If so, it contains 2 atoms of acid and 1 of alkali, that is, 55 to 60; but in addition to this, it has also water, for when procured from its solution by slow evaporation, it is deposited in the crystalline form, taking water of crystallization with it.

Bi-carbonate of potass is decomposed by heat; the excess of carbonic acid being disengaged, and carbonate left, and hence a method of procuring this salt when required pure for particular purposes.

It is soluble in about 4 parts of water, forming a transparent colourless solution, which renders vegetable blues green; so that the acid, even in this, is not sufficient to neutralize the alkali.

If the salt be put into boiling water, it is dissolved, but at the same time decomposed, carbonic acid being driven off; and hence the necessity, when evaporating the solution to obtain crystals, of keeping the temperature below the boiling point.

Like the carbonate, it is decomposed by the acids.

Bi-carbonate of potass, it has been already mentioned, is prepared by passing a stream of carbonic acid gas through the solution of the carbonate. As the acid is absorbed, a flocculent matter is deposited, which is silica, so that it is necessary, after the gas ceases, to be taken up, to filter, and the liquor must then be evaporated by a heat not exceeding 180, lest the excess of carbonic acid should be driven off.

Bi-carbonate of potass is used in medicine as an antacid, particularly in union with stomachics, as preparations of iron. It is employed in making effervescent draughts, by adding to it some of the weak vegetable acids. *(See Citric Acid.)*

Carbonate of Soda.

The properties of the salts formed by the union of soda and carbonic acid are very nearly the same as those of potassa.

Carbonate of soda, commonly called *soda*, crystallizes in octohedrons, composed of two four-sided pyramids, joined by their bases, and truncated at their summits. Its taste is the same as that of carbonate of potass. It is soluble in about 2 of cold, and in rather less than its own weight of boiling water, forming a transparent colourless solution, which changes blues to green; so that in this, as in the carbonates of potass, the acid is not in sufficient quantity to neutralize the soda.

When heated, it undergoes the watery fusion, and becomes a white powder, losing about 63 per cent. which is water of crystallization. When exposed to air, it effloresces, in this respect differing from that of potass, which deliquesces.

The action with sulphur, chlorine, iodine, and acids, is the same as that of the carbonate of potassa.

Different statements have been given of the composition of this salt. They are as follow:

	Bergman.	Klaproth.	Kirwan.	Thomson.
acid,	16	16	14.42	14.16
soda,	20	22	21.52	20.60
water,	64	62	64	65.24

That of Klaproth seems the most correct, because it very nearly agrees with the theoretic composition, which makes it consist of

1 atom acid,	27.5	or	15.27
1 atom soda,	40.		22.23
10 atoms water,	112.5		62.5
making its atom	180.		100.

Carbonate of soda is generally procured by the combustion of sea-weeds, and plants growing near the sea; the produce of the former is called *kelp*, of the latter *barilla*. Barilla is made principally along the shores of the Mediterranean, by burning different species of *salsola* and *salicornia*, for which purpose they are collected in Autumn, and laid on the ground to dry. Holes, each capable of holding about a ton, are dug in the earth, and over these are placed bars of iron, on which the plants, mixed with straw or reeds, are burned, portions of the mixture being thrown in, when the former is nearly consumed. During the combustion, the product undergoes a sort of fusion, and it is well stirred; and when the pits are full, they are covered with earth till it cools, after which it is removed, and broken to pieces.

Kelp is prepared nearly in the same way, from the different sea-weeds, which are cut in June and July, and exposed on the rocks till they become dry, care being taken to keep them from rain. They are then burned, either in pits dug in the sand, or on the surface of the ground, surrounded by stones, a fire being previously kindled, to promote the combustion. When a considerable quantity of the ashes is collected, the heat is sufficient to fuse them, after which they are well stirred; and in this way the process is carried on for several days.

The product is then covered till it becomes cold, and afterwards broken to pieces.

Kelp and barilla contain a number of substances, as lime, magnesia, sea sand, charcoal, and different salts, the principal of which is carbonate of soda, the former having from 3 to 6, and sometimes 8 per cent. the latter from 12 to 15, and occasionally, though rarely, about 17. Besides these, they contain iodine in the state of hydriodate.

The solution of the plants that yield kelp and barilla, have been found to contain muriate of soda and sulphate of potass, so that during the incineration, the sulphate is decomposed, its oxigen combining with the carbon to form carbonic acid, and its alkali with the muriatic acid of the sea salt, by which soda is liberated, and unites with the carbonic acid, and hence the origin of the carbonate of soda.

Kelp and barilla are used for yielding carbonate of soda. For this purpose, they must be dissolved in boiling water, the solution filtered, and evaporated to dryness. The residuum must be again dissolved, and the fluid slowly evaporated, to allow the impurities to be deposited, and after these are removed, the process is continued, and carbonate of soda is procured.

Kelp and barilla are used, also, in their entire state, for soap-making, and in the manufacture of glass; in the former, owing to the soda they contain; in the latter, owing partly to it, partly to other substances, which are necessary ingredients in some kinds of glass. *(See Soap and Glass.)*

As the different kinds of kelp and barilla afford different quantities of soda, it is of importance to be able to know how much they contain, as on this depends their value. *(See Appendix.)*

Sub-carbonate of soda, is used for the same purposes as sub-carbonate of potassa.

Bi-Carbonate of Soda.

When a stream of carbonic acid gas is passed through

a solution of carbonate of soda, it is converted into bi-carbonate, the properties of which are nearly the same as those of the other, and as the name shews, having twice the quantity of acid. It is soluble, but the solution has not been made to afford crystals, hence the bi-carbonate is usually sold in powder. It has the same effect on vegetable blues as solution of the carbonate. It is employed for the same purposes as bi-carbonate of potass.

Carbonate of Ammonia.

When carbonic acid and ammonia, in the gaseous form, are presented to each other, they unite and form a white powder. These substances, by their union, produce two salts, the one containing equal volumes, the other 2 of alkali and 1 of acid. The latter is the carbonate, the former bi-carbonate. Since the ingredients thus unite volume to volume, it is easy to ascertain the proportions; in the former, they must be as the specific gravities; in the latter, as twice sp. gr. of the alkali to once that of acid.

The salt found in commerce, and which is commonly called sub-carbonate of ammonia, is different in its composition from both of the above. According to Phillips, it is composed of

acid	55.93	= 3 atoms	= 27.5
alkali	28.81	= 2 atoms	= 42.5
water	15.26	= 2 atoms	= 22.5
	100		92.5

He has therefore proposed to call it a *sesqui-carbonate*, because it contains once and a half as much acid as exists in the carbonate, that is, an atom of alkali to $1\frac{1}{2}$ of acid; or, to get quit of the $\frac{1}{2}$ atom, it is said to contain 2 of alkali to three of acid.

This salt is usually obtained in the state of a hard compact crystalline mass, with some degree of transparency. It has the taste and odour of the alkali. It is soluble in

about 2 of cold, and in less than half its weight of water, a little below the boiling point, the solution changing blues to green.

When exposed to heat, it is sublimed, and condenses unchanged in its properties in dendritic crystals, the temperature necessary for the sublimation being below 212; hence we cannot employ boiling water to dissolve it.

On exposure to air, it is decomposed; it loses its ammoniacal odour, and falls into powder, owing to the loss of part of its acid and alkali, an atom of each of which is expelled, so that it is then composed of

2 atoms acid, 1 atom alkali, 2 atoms water,

and has therefore become bi-carbonate.

All the acids decompose it, disengaging its carbonic acid.

Potassa and soda also decompose it; they unite with its acid, and set its alkali free. The carbonates of the same alkalies also effect its decomposition; they deprive it of its acid, and are themselves converted to bi-carbonates, and hence a method at one time followed in preparing them, but now given up as too expensive.

Carbonate of ammonia is found in springs in the neighbourhood of volcanoes. It is almost always obtained by the decomposition of animal matter, as horns, hoofs, and bones, which contain the ingredients of which it is composed, carbon, oxigen, hydrogen, and nitrogen. These are subjected to heat in close vessels, by which their elements enter into a new state of combination, and new compounds are formed. Part of the carbon and oxigen produce carbonic acid, part of the hydrogen and nitrogen ammonia, which come off together in the state of carbonate, and is condensed in receivers. It may also be obtained by the decomposition of another ammoniacal salt, the muriate, by means of carbonate of lime. *(See Lime.)* It is employed in medicine internally, as a diaphoretic; externally, when mixed with oil, as a rubefacient.

Phosphates.

Phosphoric acid unites with the alkalies, and forms *phosphates*. They have, however, been very little examined, and are not put to any particular use.

The only phosphate of any interest, is that with soda. It may be formed by the direct union of its ingredients, but it is never prepared in that way. It is procured by the decomposition of the earth of bones, a compound of lime and phosphoric acid. *(See Lime.)*

Phosphate of Soda.

This salt was discovered in urine by Hellot in 1737, but we are indebted to Klaproth for the discovery of its composition. It crystallizes in rhomboidal prisms. It has a cooling, not unpleasant taste. When subjected to heat, it undergoes the watery fusion, and afterwards melts into an opake glass. When exposed to air, it effloresces. It is soluble in about 4 of cold and 2 of boiling water, but the solution is with difficulty made to crystallize, unless there is a slight excess of alkali, and hence the salt of commerce is usually alkaline.

According to Thomson, (First Pr.) phosphate of soda is composed of

acid	16.39	=	1 atom	=	35
soda	18.73	=	1 atom	=	40
water	64.88	=	12 atoms	=	135
	100	its atomic weight being			210

Phosphate of soda is decomposed by nitric, sulphuric, and muriatic acids, which deprive it of part of its base, and leave the remainder in union with the whole of the phosphoric acid, forming a bi-phosphate, containing therefore double the quantity of acid that exists in the other.

The phosphate is used in medicine as a mild purgative, for which, owing to its less nauseous taste, it is better adapted than some of the others. As it is fused at a low

temperature, and as in this state it acts powerfully on metallic compounds, it is employed as a *flux* in their analysis.

Phosphate of Ammonia.

This salt exists also in urine. It crystallizes in octohedrons. It is soluble in water, the solution having a disagreeable bitter taste.

When exposed to heat, it is decomposed, the ammonia is expelled, and the acid is left pure. If subjected to heat with charcoal, the acid is likewise decomposed, its oxigen uniting with the charcoal, while the phosphorus distils over.

When phosphate of ammonia is mixed with phosphate of soda, and heat applied, the ammonia is expelled, and super-phosphate of soda is formed.

Borates.

The only borate of any importance, is that with soda, long known by the name of *borax*, and in which the boracic acid is not in sufficient quantity to neutralize the alkali; and hence it has been called

Sub-Borate of Soda.

It was noticed so early as the 9th century; but its composition was not known till 1732, when it was pointed out by Geoffrey.

It crystallizes in six-sided prisms. It has a styptic cooling taste. It is soluble in 20 of cold, and in 6 of boiling water, the solution changing blues to green. When exposed to a moderate heat, it liquefies, swells, and parts with its water of crystallization, becoming a light spongy mass, commonly called *calcined*, or *burnt borax*. By continuing the heat, the salt is fused; and, on cooling, becomes a transparent glass, but without undergoing any change in its qualities.

The composition of borax, as given by Gmelin and Bergman, is about 35 of acid, 17 of alkali, and 48 of water. Dr Thomson, however, in his late experiments, (First Pr.) considers it as composed of

acid,	21.05	= 2 atoms	= 30
soda,	31.57	= 1 atom	= 40
water,	47.37	= 8 atoms	= 90
	99.99	its atom being	160.

Borax is easily decomposed by the stronger acids, which unite with the soda and set the acid free, and hence the method of procuring it. For this purpose, two ounces of the salt are dissolved in boiling water, so as to make a saturated solution, to which one ounce of muriatic acid is to be added; and as the solution cools, crystals of boracic acid are deposited. After pouring off the solution of muriate of soda, they are to be washed with a little cold water, and then heated, to drive off any superfluous muriatic acid.

Borax is a natural production. It is found in great abundance in a lake in Thibet, from which it is dug and sent to Europe, under the name of *tincal*. It is not, however, in this state pure; it is enveloped in a fatty matter, from which it is freed by exposure to a red heat, and afterwards dissolving it in water, and crystallizing it.

Borax is employed in solution as a gargle; and, when calcined, as an application to aphthous spots, either in powder or mixed with honey. From the power it possesses of uniting with earthy matter, and making it soluble, it is used in the analysis of minerals; and it is owing to this also, that it is employed in making the finer kinds of glass, with the view of imitating gems. It is used also in soldering metals, because by the heat it melts, and covers their surface, and then protects them from the action of the air, at the high temperature to which they are exposed. It is applied also, with great advantage, in welding iron to steel.

Sulphates.

Sulphate of Potassa.

Sulphate of potassa, or *vitriolated tartar* of commerce, is obtained in six-sided prisms, terminated by six-sided pyramids. It has a bitter taste; is sparingly soluble in water, requiring about 16 parts at a natural temperature, and 5 at a boiling heat, for solution. It decrepitates, owing to the small quantity of water it contains: but this is not water of crystallization; it has been merely carried along with it during its deposition from solution.

Sulphate of potassa is composed of an atom of each of its ingredients, and hence its composition is

1 atom acid,	50	or 45.45
1 atom potassa,	60	54.55
its atom being	110	100.

Perhaps the most important action of sulphate of potass, is that with carbon. When heated with charcoal, it undergoes decomposition, the carbon uniting with the oxigen of both of its ingredients, and leaving the sulphur and potassium to form a *sulphuret*. As this sulphuret, when put into water, becomes a hydro-sulphuret, the decomposition of sulphate by charcoal is sometimes practised with the view of preparing this salt.

The explanation given of the action between sulphate of potass and charcoal, may be considered applicable to many other sulphates with oxidized bases,—the charcoal depriving them of their oxigen, and converting them to *sulphurets*; and hence a method of preparing the sulphurets of those metals which cannot be obtained pure, so as to cause them to enter directly into union with sulphur.

Sulphate of potass may be procured by the addition of the acid to the alkaline carbonate; but a cheaper method of preparing it is by the saturation of the acidulous

salt, left in the preparation of nitrous acid, in which nitrate of potass is decomposed by sulphuric acid, (p. 388). For this purpose, the saline mass being dissolved in water, a solution of carbonate of potass must be added, till the excess of sulphuric acid is saturated; and which is known by its not reddening a test paper.—Or the solution may have lime added to it; which, by uniting with the excess of acid, will form sulphate of lime, which is deposited, while the sulphate of potass is left in solution, and may be obtained by filtration and evaporation.

The salt left in the preparation of nitrous acid, it has been already mentioned, is a super-salt. It has been found, by Wollaston, to contain double the quantity of acid that exists in the neutral sulphate; and if so, it is composed of an atom of base to 2 of acid, and is therefore a *bi-sulphate*. It is used, as stated, for yielding neutral sulphate, and it is sometimes employed when an acid is required free from water.

Sulphate of Soda.

Sulphate of soda was discovered by a German chemist of the name of Glauber, who called it *sal mirabile*, but after whom it has been termed *Glauber salt*. It was also, before the establishment of the French nomenclature, called *natron vitriolatum*, or vitriolated soda.

Its crystals are transparent, six-sided prisms terminated by dihedral summits, the taste of which is strongly saline and bitter. It is soluble in 2.8 of water, at 60, and in 0.8, at 212. Gay Lussac has, however, stated a very remarkable fact with respect to its solubility; that after being freed of water of crystallization, it is more soluble at 91½ than at any other temperature, 100 of water at 32 dissolving 5, at a boiling heat 42½, and at 91½ no less than 50.

When heated, it undergoes the watery fusion, and on exposure to air effloresces, losing about 56 per cent. of its weight, and a light white powder is formed.

It is a compound of

1 atom	50 or	24.7
1 atom	40	19.3
10 atoms	112.5	56
	202.5	100

It is decomposed by charcoal in the same way as sulphate of potass, provided its water of crystallization has been previously expelled, and sulphuret of sodium is formed.

Sulphate of soda is found native in some mineral waters. It is also observed as an efflorescence on the walls of old buildings. It is generally obtained, however, from the residue of the process for procuring muriatic acid, and which consists in adding sulphuric acid to sea salt, by which a sulphate of soda mixed with a little super-sulphate is formed. When to this carbonate of soda is added, the carbonic acid is disengaged, and the excess of sulphuric acid neutralized by the soda of the carbonate, so that, by filtration and evaporation, crystals are procured.

Sulphate of soda is also a residuum in the manufacture of other substances, as sal ammoniac. *(See this.)*

Sulphate of soda is employed in medicine as a purgative. By far the most important process carried on with it, is decomposing it, so as to make it yield its alkali, which is so valuable an article of commerce. *(See Muriate of Soda.)*

Sulphate of Ammonia.

Sulphate of ammonia may be formed by the decomposition of the carbonate by muriatic acid, but it is never prepared in this way. It exists in soot, the acid being formed by the combustion of the sulphur always existing in coal, and the ammonia by the union of part of its hydrogen and nitrogen. In the preparation of coal gas, an ammoniacal liquor is collected in part of the apparatus, which, when mixed with oil of vitriol, also affords sulphate of ammonia. The only use to which this salt is

applied, is in the preparation of muriate of ammonia. *(See Mur. Ammonia.)*

Chlorates.

Before the discoveries of Sir H. Davy with respect to chlorine, the chlorates were called *hyper-oxi-muriates*, from the idea that they contained an acid, having a still larger proportion of oxigen than was supposed to exist in oxi-muriatic, and hence its name *hyper-oxi-muriatic*. It has been already mentioned, that according to the new doctrine, this acid is a compound of chlorine and oxigen, and called *chloric acid*, its salts being *chlorates*. The chlorate, particularly that of potassa, has excited considerable interest, owing to the peculiarity of its properties, and to its having, by its decomposition, afforded substances with which we were not previously acquainted.

Chlorate of Potassa.

This salt was first mentioned by Higgins, but he does not seem to have been aware of its composition, having supposed it to be nitre, to which, in some of its properties, it has a strong resemblance. It was afterwards noticed by Berthollet and Chenevix, and more lately examined by Davy, and Gay Lussac and Thenard.

It is obtained in general in small thin laminæ, of a silvery whiteness, but when deposited slowly from its solution, it is in the form of obtuse rhomboidal plates. It has a cooling disagreeable taste, resembling that of nitre. It requires 16 of cold, but only 2 of boiling water, for solution.

When subjected to heat, it undergoes decomposition, and oxigen gas, equal in weight to about 1-3d of the salt, is disengaged, and hence a method of preparing this elastic fluid, when required pure for particular purposes. All that is necessary, is to put any quantity of the salt into a retort, and apply heat as long as gas comes off. After

the action is over, there remains a white saline-looking matter, which, according to the new doctrine, is chlorid of potassium.

Berzelius found, that 100 gr. previously freed from water, yielded 38.69 of oxigen, leaving a residue of chlorid of potassium, weighing 60.94, composed of 28.87 chlorine, and 32.07 potassium. The latter requires 6.41 of oxigen, to convert them to potassa, subtracting which from that given off by the salt, leaves 32.28 to have been in union with the chlorine, to form chloric acid, so that chlorate of potass is composed of

chlorine, 28.87
oxigen, 32.28 } = 61.15 of acid

potassium, 32.07
oxigen, 6.41 } = 38.48 potassa

and as 61.15 : 38.48 :: 95 : 59.7,

so nearly 60, that we may consider it a compound of

1 atom acid,	95	or 61.29
1 atom potassa,	60	38.71
its atom being	155	100

Chlorate of potassa acts with astonishing violence on inflammables. Those already described detonate with it either by friction or percussion, the action being the same in all, but of course the product differing according to the inflammable employed.

When phosphorus is mixed with it, and the mixture, made into a small packet, is struck with a hammer, it explodes with great force, rendering the experiment dangerous, so that it ought not to be performed on more than a quarter of a grain. Charcoal in powder also acts in a similar way, and the same is the case with sulphur; indeed, the mixture with it explodes by friction, equal parts of the powder of the salt, and flowers of sulphur, when rubbed in a mortar, exploding with great violence. This shews the necessity of operating on small quantities, and, in making the mixtures, the materials ought to be reduced to powder *separately*, and in each experiment, only 2 or 3 grains should be used, and

mixed on paper by means of a piece of wood. The action in these cases is supposed to be owing to the ease with which the salt parts with oxigen to the inflammable, the friction or percussion favouring it, probably by the generation of a little heat.

The action between chlorate of potassa and the acids is important, particularly with muriatic and sulphuric, as by them it is decomposed, and the two oxids of chlorine are disengaged, the former yielding the protoxid, and the latter the peroxid.

When a few grains of the salt are thrown into about an ounce of muriatic acid, there is an effervescence, and the fluid acquires the property of destroying vegetable colour. If the acid be diluted, the action is more gradual, and protoxid of chlorine is disengaged, and hence the method of preparing it. For this purpose we must employ a mercurial trough, or the gas may be more easily collected by the displacement of the air of the apparatus. Having put into a retort, *(cut, p.315.)* half an ounce of the chlorate, pour in an ounce of a mixture of equal parts of muriatic acid and water, and apply heat by means of a spirit lamp, with a small wick, and held at the distance of a few inches. As the gas comes off, it gradually pushes out above it the lighter atmospheric air, and when, from the appearance of the receiver, it is supposed to be full, it must be removed, and another substituted, so that in this way a sufficient quantity may be collected for experiment.

The chemical action in this instance is accounted for by the decomposition of both acids. Part of the muriatic unites with the potassa of the chlorate to form a muriate, while chloric acid is disengaged, and acts on the remainder of the muriatic, the hydrogen of which combines with as much oxigen from the other as will form water, the remaining ingredients, that is, the chlorine of both acids, unite with the rest of the oxigen to generate the protoxid.

For each atom of chloric acid decomposed, 2 of muria-

tic are necessary, and 3 of protoxid and 2 of water must be set free.

For 1 atom chloric acid = { chlorine 1, oxigen 5

2 atoms muriatic acid = { 2 chlorine, 2 hydrogen

and 2 water = { 2 hydrogen, 2 oxigen

and 3 protoxid of chlorine = { 3 chlorine, 3 oxigen.

It frequently happens, however, that a little uncombined chlorine comes over mixed with the protoxid; but the quantity must be very small, as is proved by the gas collected by the displacement of the air not acting on copper leaf, which it ought to do if it contained much chlorine. The disengagement of this gas is accounted for by the complete decomposition of some of the chloric acid, the oxigen from which must have been taken away by the hydrogen of the muriatic.

The action with sulphuric acid is no less important, per-oxid of chlorine being formed, and hence the method of preparing it. It may be obtained as recommended by Gay Lussac, by mixing the acid with the salt very cautiously, and keeping them cold to prevent action. The mixture is then put into a retort, and by plunging the body of this into warmish water, the gas will come off, and may be collected either in a mercurial trough, or by the displacement of air, using the same apparatus as that for the preparation of the protoxid. A simple method of procuring the gas is to collect it in the same vessel in which it is prepared, and in which way it is sufficiently pure for the experiments that may be performed on it, with the view of shewing its properties. For this purpose, into a strong glass tube of about 6 inches in length, and half an inch in diameter, place 2 or 3 grains of salt, and having inserted a long funnel, pour in a drop or two of acid, and instantly remove it, after which put in a cork loosely into the mouth of the tube, and place the end of it into warmish water, so

as just to cover that part containing the mixture. The action will commence, by which the peroxid is disengaged, and pushing up the lighter air which escapes, the tube becomes full. As it is dangerous, owing to its explosive power, to collect much of the gas in one receiver, when required in considerable quantity, it is better to have a number of tubes, into each of which the mixture of acid and salt can be put.

In this experiment the action is easily explained. The sulphuric acid, owing to its affinity for potassa, liberates the chloric acid, but which, instead of remaining in that state, undergoes decomposition, one part taking oxigen from the other. That which loses it becomes peroxid of chlorine, the other, which has acquired it, is changed to per-chloric acid, and is left in union with some of the potass, forming *per-chlorate* of potass; so that the saline matter at the bottom of the tube is a mixture of bi-sulphate and per-chlorate, and which can be separated by solution and crystallization. The latter being least soluble, is of course first deposited.

It is probable that three atoms of chloric acid are decomposed, and that 2 of the oxid, and 1 of the per-chloric acid, are produced.

$$3 \text{ atoms of chloric acid} = \begin{cases} 3 \text{ chlorine} \\ 15 \text{ oxigen} \end{cases}$$

will yield, by decomposition,

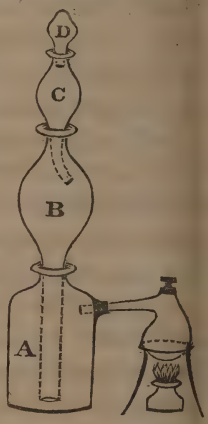
$$2 \text{ atoms of peroxid of chlorine} = \begin{cases} 2 \text{ chlorine} \\ 8 \text{ oxigen} \end{cases}$$

$$1 \text{ atom per-chloric acid} = \begin{cases} 1 \text{ chlorine} \\ 7 \text{ oxigen} \end{cases}$$

When the per-chlorate of potassa obtained in this process, is exposed to heat, it yields oxigen gas. When heated with sulphuric acid, it is decomposed, the acid uniting with the alkali, and setting free per-chloric acid. Hence the method of preparing it.

If sulphuric acid be poured on chlorate of potassa, mixed with any inflammable matter, there is immediate combustion, owing to the action of the disengaged peroxid on the inflammable, *(see p. 260.)*

Chlorate of potassa is always procured by passing a stream of chlorine gas slowly through solution of potassa, and at the same time subjected to pressure, so that Nooth's apparatus may be used, or, which answers better, one of this form. It consists of a bottle, A, having two apertures, into one of which is inserted the mouth of a retort, and into the other the tube of the vessel, B, which passes down to the bottom of it. Into the upper aperture of B, is placed another similar vessel, C, with a bent tube, and having a stopper at D. Into A is placed the fluid to absorb the gas, being brought as high as the mouth of the retort, and as the tube of B is immersed in it, it acts as a valve; for when the gas flows into A, it raises it into B, thus it prevents its escape, except when accumulated, in which case, it has to pass through a column of fluid; besides, the gas in A always subject to pressure, in proportion to the height of the apparatus. The use of C is to receive the fluid forced up, when gas collects in the upper part of B.

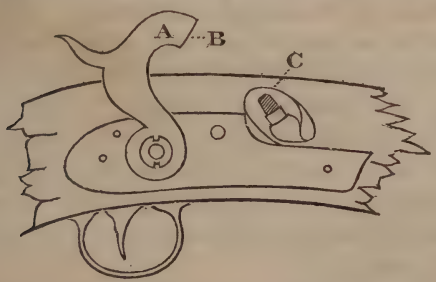


For preparing the chlorate, the mixture to generate chlorine, (oxid of manganese 1 part, muriatic acid 4, or oxid of manganese 1, sea salt 4, water and sulphuric acid each 2,) is placed in the retort A, the alkaline solution in B. On applying a slight heat, the gas comes off, and, in passing through the fluid, is absorbed; and when it ceases to be so, the liquid is filtered and evaporated, by which crystals of chlorate are obtained.

In this instance, during the passage of the chlorine through the fluid, water is decomposed, the ingredients of which, uniting with the chlorine, form chloric and muriatic acids, and these combining with the alkali, produce chlorate and muriate of potass; and as the former is the least soluble, it is first deposited during the evaporation. Now, as chloric acid contains 1 of chlorine and 5 of oxigen, and muriatic acid an atom of each of its ingredients,

there must be the decomposition of at least 5 atoms of water, and by which only 1 of chloric, but 5 of muriatic acid will be produced, the latter uniting with 5 of alkali; so that there is in the process a great waste both of chlorine and of potass, and hence the reason of the chlorate being so expensive.

From the great explosive power of mixtures of chlorate of potassa and inflammables, it was recommended to employ it, instead of nitre, in the manufacture of gunpowder; indeed, an attempt was made in France to this effect, but the moment the mixture was rubbed, it exploded, and proved fatal to some of the workmen, so that the process was abandoned. But, besides the danger, the expense of preparing it precludes its use. It has, however, been recommended by Mr Forsyth as a priming for his patent firelock, now known by the name of *percussion lock*. In those first used, the priming was kept in a reservoir attached to them, but explosions sometimes happened; accordingly, various improvements have been made on it. That now in common use, and which is not only the simplest, but the safest, consists merely of a small hammer, A, fixed to the trigger, and terminated by a little cup at B, fitting the projection C, in which is the



touch-hole, communicating with the barrel. A number of small copper caps are made to fit accurately the projection C, and into these is placed a little of the explosive mixture. After the barrel is loaded, a cap is put on, and the hammer brought down cautiously on it. When the piece is to be discharged, the hammer is brought to full cock, and by drawing the trigger, it comes down with a

smart blow on the cap, and explodes the mixture, the flame from which rushes through the touch-hole, and sets fire to the powder. This lock is attended with several advantages. There is no chance of the priming being injured by moisture, by which the common ones so frequently *hang fire*, and indeed often cannot be used during wet weather, and there is little danger to be apprehended from the hammer being cocked accidentally, the spring being much stronger than in flint locks. Different mixtures have been used. That recommended by Forsyth, was the salt with sulphur and charcoal; but the substance commonly called crude antimony, and which is a compound of the metal antimony and sulphur, is generally employed, being mixed with about an equal quantity of the salt.

Chlorate of potass is likewise employed as a means of procuring a light. The action with sulphuric acid and inflammable matter, has been already noticed. It is in this way that a light is obtained. The salt, after being reduced to powder, is mixed on a piece of paper, with an equal bulk of the powder of white sugar, and made into a thick paste with mucilage, or it may be mixed with flour, and made into a paste with water, in which state it is put on the end of a small sulphur match, taking care to leave some of the sulphur uncovered. When this is dipt into oil of vitriol, there is an action similar to that already described with phosphorus, by which the sugar is inflamed, and kindles the sulphur. These matches are in general put up into a box, with a small bottle of acid, and a wax taper. They must be kept dry, and the acid ought to be frequently renewed, because it is apt to absorb moisture, particularly if the stopper has been often removed.

By this action, pieces of artillery may also be discharged, for if a small pipe, filled with the mixture, be placed in the touch-hole, by putting on a drop of acid, it is kindled, and the flame rushes into the barrel.

Chlorate of Soda.

This salt may be prepared in the same way as chlorate

of potass, and its properties, particularly with inflammables and acids, are the same.

Chlorate of Ammonia.

It has been already mentioned, that by bringing chlorine gas over solution of ammonia, chlorid of nitrogen is formed, (p. 262.) and when chlorine and ammonia, in the state of gas, are brought into contact, they form muriate of ammonia, (p. 381.) We cannot, therefore, prepare chlorate of ammonia by a process similar to that by which the other chlorates are formed. It may be procured by the direct union of its ingredients, but its properties have not been examined, and it is not put to any use.

Iodates.

The iodates of the alkalies were discovered nearly about the same time by Davy and Gay Lussac, but the first account of them published was by Davy.

Iodate of Potassa.

This salt is procured by a process similar to that by which the chlorate is prepared, by shaking iodine in solution of potass. Of course the action is the same, the water communicating its ingredients to the iodine, to form iodic and hydr-iodic acid, which, combining with the alkali, produce iodate, and hydr-iodate. A white powder is formed, consisting of the two salts, which can be separated by the action of alcohol; for when it is digested with it for some time, the latter only is dissolved, so that the iodate is obtained pure.

Iodate of potass is decomposed by heat, giving off oxigen, and leaving iodid of potassium in the retort, 100 gr. yielding 22.5 of gas, and of course 77.5 of iodid. From this mode of analysis, it has been found to consist of

acid, - 78
potass, - 22
and as 78 : 22 : : 20.5 : 58,
so nearly 60, that we may consider it composed of

1 atom of acid,	-	205 or	77.4
1 atom of potassa,	-	60	22.6
its atom being	-	265	100

Iodate of potass detonates with inflammables, though by no means with so much violence as the chlorate.

Iodate of Soda

Is obtained in the same way, and is possessed of similar properties. Its composition is,

1 atom acid,	- -	205 or	84
1 atom soda,	- -	40	16
and its atom,	- -	245	100

Iodate of Ammonia.

In the preparation of this iodate, iodic acid is saturated by the addition of carbonate of ammonia. It detonates also with inflammables.

Arsenates and Arsenites.

Arsenate of Potassa.

When equal parts of arsenous acid and nitre are fused, and the heat continued till the red fumes, which at first come off, cease to be disengaged, a white saline mass is obtained, soluble in water, and on evaporation giving crystals of arsenate of potass, but with excess of acid. Here the arsenous acid, having acquired oxigen from the nitric, has been converted to arsenic acid, and united with the potassa, nitric oxid coming off, and forming the red fumes of nitrous acid.

Arsenite of Potassa.

This salt is prepared by boiling solution of sub-carbonate of potass with arsenous acid. They enter into union, and form a substance long known by the name of *Fowler's solution*, much employed in medicine, in cases of periodic headache, obstinate rheumatisms, &c. It is the *solutio arsenitis Potassæ* of the Pharmacopœia.

Seleniates.

Selenic acid unites, in three different proportions, with the alkalies, and forms *seleniates*, *bi-seleniates*, and *quadri-seleniates*. They are procured by the direct union of their ingredients, but they do not present any thing interesting.

Cyanates.

It has been already mentioned, that when cyanogen is passed through alkaline solutions, the water is decomposed, giving rise to the formation of cyanic and hydro-cyanic acids, which are left in union with the alkali. Cyanate of potassa is more easily procured by exposing to a low red heat, a mixture, of equal weights, of the salt called ferro-cyanate of potass, and of black oxid of manganese, by which the oxigen of the latter, and the cyanogen of the former, unite to produce cyanic acid, which combines with the potass. The cyanate thus formed may be dissolved by warm alcohol, which, when it cools, deposits it in small plates.

When cyanate of potass is heated, particularly in solution, it is decomposed, and resolved into carbonic acid and ammonia; and the same occurs on the addition of any acid, which, uniting with its base, causes the expulsion and decomposition of the cyanic acid.

SALTS WITH HYDR-ACIDS.

Hydro-Sulphurets, and Sulphuretted Hydro-Sulphurets.

The salts formed by the union of the alkalies with sulphuretted and super-sulphuretted hydrogen, are a very interesting class of compounds, from the peculiarity of their properties, and from the important actions that take place during their preparation. As yet, our knowledge of them is but limited; and, unluckily, the nomenclature is imperfect and confused. According to the rule already laid down, of giving compounds names derived from those of their ingredients, sulphuretted hydrogen should be called *hydro-sulphuric acid*, and its salts, *hydro-sulphates*, by which we would at once be informed of their composition.

The nomenclature of the compounds of the bases, and super-sulphuretted hydrogen, is still more imperfect. They were first called, by Berthollet, *hydrogenated sulphurets*, and afterwards by Chenevix, *hydroguretted sulphurets*. Kirwan, who first gave the name of super-sulphuretted hydrogen to this compound of hydrogen and sulphur, proposed to call its salts *super-sulphuretted hydro-sulphurets*, which was shortened to *sulphuretted hydro-sulphurets*, the term now in general use.

Were we to adopt a nomenclature similar to that applied to other acids, super-sulphuretted hydrogen, as it contains less hydrogen than there is in sulphuretted hydrogen, should be called *hydro-sulphurous acid*, and its compounds, *hydro-sulphites*.

Hydro-sulphate, or Hydro-sulphuret of Potassa.

This salt is obtained by passing a stream of hydro-sulphuric acid, (sulphuretted hydrogen), through solution of potassa, by which a transparent colourless fluid is formed, which yields long prismatic crystals, not unlike those of sulphate of soda.

They have no smell when dry; but when exposed to

air, they attract moisture, and emit a fetid odour. They are soluble in water; affording a solution easily decomposed by exposure to air, oxigen being absorbed, which, uniting with part of the hydrogen of the acid to form water, leaves an excess of sulphur, thus producing hydro-sulphurous acid, (super-sulphuretted hydrogen), and which, with the base, becomes hydro-sulphite, (sulphuretted hydro-sulphuret), of a brownish colour.—Hence the necessity of keeping the solution in well-corked phials.

On the addition of any acid to the solution of the hydro-sulphate, there is an effervescence, owing to the disengagement of hydro-sulphuric acid, the other uniting with the base, and forming a *transparent* solution.

Though the hydro-sulphate is generally procured by the transmission of the acid gas through the alkaline solution, other methods are followed. It has been already mentioned, *(p.* 408.*)* that when sulphate of potassa, free from moisture, is heated with charcoal, sulphuret of potassium is formed. If this be thrown into water, there is a double decomposition, and hydro-sulphate of potassa is the result.

Hydro-sulphate of Soda.

This salt may be prepared in the same way, and its properties are similar to those of the salt with potassa.

Hydro-sulphate of Ammonia.

When equal volumes of hydro-sulphuric acid and ammonia are mixed, they combine, and form white clouds, which condense on the inside of the vessel. The salt may be also prepared by passing the gas through solution of ammonia, till it ceases to be absorbed. Transparent needle-shaped crystals are formed, which are so volatile, that when placed at the bottom of a bottle they very soon sublime. When exposed to the air, they attract moisture, and are decomposed; and the same happens also when they are in solution, there is an absorption of oxigen, and a gradual conversion to hydro-sulphite.

This salt was recommended by Rollo under the name of Hepatised Ammonia, in diseases of increased action, particularly in diabetes, for which reason it has been introduced into the Pharmacopœia.

Hydro-sulphite, or Sulphuretted Hydro-sulphuret of Potassa.

It has been already stated, that when solution of hydro-sulphate is exposed to air, it becomes, from the absorption of oxigen, and consumption of part of the hydrogen, a hydro-sulphite; hence one method of preparing this compound; but it is not generally resorted to, as it can be procured by a much easier process, though not quite pure, but sufficiently so for the purposes to which it is usually applied. When sulphur and potashes are fused together, the substance commonly called *sulphuret of potassa* is formed; but which, it was formerly mentioned, *(p. 398.)* may be considered a mixture of sulphate and hydro-sulphite of potass, so that, by dissolving it in water, a solution of the latter is procured, containing very little of the former, because it is sparingly soluble.

Another mode of preparing it is, to boil solution of potassa on flowers of sulphur, till it becomes of a deep-brown colour, taking care to shake the vessel frequently, to prevent the mixture from boiling over. The same action goes on in this case as when the sulphur is heated with potashes, the water giving both of its ingredients to the sulphur, to produce sulphuric and hydro-sulphurous acids, which uniting with the alkali, form sulphate and hydro-sulphite; and as the former is sparingly soluble, the greater part of it is deposited as the fluid cools.

Though the substances formed by the action of sulphur on potashes, whether in the dry or in the liquid way, have been described as containing sulphuretted hydro-sulphuret, very different statements have been given by other chemists of their composition. It was at one time imagined, that when sulphur and carbonate of potass were heated, the carbonic acid gas was set at liberty, while the sulphur and *alkali* combined to form a sulphuret.

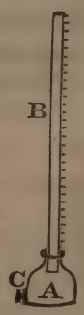
Others, as Vauquelin, (An. de Ch. et de Ph. vi.) maintained that part of the potassa was decomposed; that its oxigen united with sulphur, to form sulphuric acid, so that the product was a mixture of sulphuret of potassium, and sulphate of potassa. More lately, Berzelius, (An. de Ch. et de Ph. xx.), and Berthier, (Ibid. xxii.) have endeavoured to prove that sulphuret of potassium is the product, the compound being the same as that obtained by the decomposition of sulphate by charcoal. I am inclined, however, to consider the explanation given above as the more probable; for that there is a sulphuretted hydro-sulphuret, and not a sulphuret of potassium, is evident; because, on the addition of an acid to the solution, there is not only the disengagement of sulphuretted hydrogen, but also the precipitation of sulphur,—a property peculiar to sulphuretted hydro-sulphurets; besides, when sulphur is heated with some other oxidized bases, as lime, and which can be obtained *free from water*, there is no action, the sulphur passing off in vapour; now, common potashes always contain moisture, which, by its decomposition, may give oxigen and hydrogen to the sulphur. Analogy is also in favour of this opinion. Chlorine, iodine, and phosphorus, when treated with potassa and water, cause decomposition of the latter, and formation of compounds containing oxigen and hydrogen. Sulphur belongs to the same class, for it enters also into union with both of the acidifying principles, to form acids, so that it is likely it will act with alkaline substances in the same manner. With respect to the nature of the product of the action of charcoal on a sulphate, if it be free from moisture, we know that it is a sulphuret of the metallic base, and consequently, when thrown into water, will yield hydro-sulphuret; but if the sulphate contain water, there is always produced a sulphuretted hydro-sulphuret; and that there is so, is proved by the addition of an acid to the solution, by which sulphur is precipitated.

The solution of the sulphuretted hydro-sulphuret, like that of the hydro-sulphate, is easily decomposed by

exposure to air; oxigen is absorbed, which, uniting with the hydrogen, generates water, and with the sulphur hypo-sulphurous acid, with which the alkali is left in union, forming hypo-sulphite, giving a colourless solution. As hydro-sulphate, by exposure to air, becomes hydro-sulphite, it is evident that it also, by continuance of exposure to air, will become hypo-sulphite, the fluid, from being colourless, acquiring a darker and darker colour, and again becoming colourless.

This solution is also easily decomposed by acids, which unite with the potass, and liberate the acid; but the products differ according to the method of mixing the fluids. When muriatic acid is dropt into the solution, it forms a muriate, and the hydro-sulphurous acid, when set free, is instantly decomposed, hydro-sulphuric acid is given off in the form of gas, and the fluid becomes *opake* from the deposition of sulphur; but which, instead of assuming its proper yellow colour, is white, probably from its containing a little water. If, however, instead of pouring the acid into the solution, the solution be thrown into the acid, very little of the hydro-sulphurous acid is decomposed. It is deposited in the form of a yellowish fluid of an oily consistence; and hence the method of preparing it.

From the avidity with which the solution of hydro-sulphite of potass absorbs oxigen, it is employed for ascertaining the quantity of it in air, and other gaseous mixtures. The apparatus in common use for this purpose, is the *Eudiometer* of Dr Hope. It consists of a graduated tube, B, fitted to a bottle, A, having a stopper at C. In using this, suppose the tube full of air, the bottle is to be filled with the solution, and the tube inserted, and by shaking them the whole of the oxigen will be absorbed in the course of a few minutes. After this, the apparatus is plunged into a basin of water, and the stopper, C, removed, but instantly replaced, by which the water flows in to fill up the vacuum, and the height to which it rises indicates the



quantity of oxigen consumed; taking care to have the fluid on the inside and outside on a level, and by keeping the whole apparatus in the water for some time, to have it at the same temperature as at the commencement of the experiment. Should the absorption not be complete by the first shaking, the process must be repeated till the water will not rise any farther in the tube.

In using any other gaseous fluid than air, having filled the tube, the bottle full of the solution must be placed in the same vessel with it, which is then to be inserted into the upper aperture, and the process after this must be conducted in the manner already described.

Instead of the apparatus now described, Dr Henry has proposed, that an elastic gum bottle should be used instead of the glass one. The tube, B, is fitted accurately, by grinding into another, to which the gum bottle is tied. This apparatus is used in the same way as the other, and the advantages attending it are, that as the oxigen is absorbed, the external pressure of the air causes the solution to rise to supply the vacuum, so that there is no necessity for removing the tube to admit water, by the introduction of which the solution is so much diluted, that it acts slowly on the air.



Though this method of ascertaining the proportion of oxigen, is by no means so accurate as some of the others, yet it is frequently trusted to, particularly when no great degree of nicety is required.

Since solution of hydro-sulphate of potass absorbs oxigen so easily, it is sometimes employed for preparing nitrogen. For this purpose the same apparatus may be employed as that already described, (p. 206.) and by which nitrogen was procured by means of a mixture of moistened iron filings and sulphur, the hydro-sulphite being placed in the cup. Or the solution, to the depth of about an inch, may be poured into the outer jar, and the bell-glass placed over it, and by which also the ab-

sorption will go on, and the fluid will rise to supply the place of the oxigen removed.

Hydro-Sulphite of Soda.

The solution of this substance is prepared in the same way as that of potass. Its properties are similar, and of course it may be applied to the same purposes.

Hydro-Sulphite of Ammonia.

This substance is prepared by exposing solution of hydro-sulphate to air, to allow it to absorb oxigen, or by keeping it in a phial along with flowers of sulphur, which it gradually dissolves, forming hydro-sulphurous acid, to unite with the ammonia.

Its properties are the same as those of the other hydro-sulphites.

Muriates or Hydro-Chlorates.

It has been already mentioned, that many of the chlorurets, when thrown into water, become muriates, by the oxigen uniting with the base, and the hydrogen with the chlorine. Such is the case with those of potassium and sodium. Again, on evaporating the solution to dryness, the muriate becomes chloruret, so that the substances long known by the names of muriates of potass and soda, must, if we adopt strictly the new views with respect to chlorine, be considered chlorurets. Instead of detailing the properties of these, when mentioning the action between chlorine and the metallic bases of the alkalies, I have thought proper to bring them in with the salts, because in all their actions with other substances they become muriates, by the decomposition of the water which these contain ; and therefore, in one point of view, keeping this in remembrance, we are detailing the properties not of chlorurets, but of muriates. These remarks are applicable

only to the compounds of potassium and sodium. That with ammonia is allowed by all to be a muriate.

What has been said of chlorurets, may be applied to iodurets, and to the compounds of the other bodies forming hydr-acids, as fluorine, cyanogen, and xanthogen; indeed the class of compounds containing sulphur, may perhaps also be considered in the same light. As all of these, however, also become salts when acted on by other substances, I have brought them in under this class; by which arrangement, bodies acting similarly are placed together, and their properties will, I think, be more easily understood.

Muriate of Potassa.

Muriatic acid unites with potassa, and forms a muriate, having a bitter saline taste. When its solution is evaporated, cubical crystals of chlorid of potassium are deposited, which require 3 of cold, and about $\frac{1}{2}$ of boiling water to dissolve them.

The properties of this salt have been but very little examined, and it is not put to any particular use, except in the preparation of alum; for which purpose it is in general procured from kelp and barilla, the substances employed in the manufacture of soap. After the free alkali has been extracted by the oil employed in this process, the residuary solution, when evaporated to dryness, yields muriate of potass.

Muriate of Soda.

This salt may be obtained by the direct union of its ingredients, but it is never prepared in this way. It is the principal saline substance in sea water, and in rock salt, from both of which it is always procured. On evaporating the solution, cubical crystals of chlorid of sodium are deposited; but these are sometimes of other forms, the most common of which is a hollow four-sided

pyramid, and which is occasioned by the salt crystallizing on the surface; for when the cube is first produced it sinks a little in the fluid, and acquires a layer on each of the four sides where it is in contact with it, by which it becomes heavier and sinks a little farther, when it again acquires another layer, and so on till it forms a hollow pyramidal crystal, with the apex undermost.

These crystals, when pure, are not altered by exposure to air, but the sea salt in common use deliquesces, from its containing compounds of magnesia and lime. When heated, they decrepitate, but this is not owing to water of crystallization; it is merely a little which has been taken along with the particles when deposited from solution, and must be considered therefore as interstitial. In general it amounts to about 3 per cent.

They are soluble in 2.5 of cold water, and what is very remarkable, they require very nearly as much at a boiling heat; accordingly a warm solution does not crystallize when it cools; the crystals are obtained by evaporation.

As chlorid of sodium consists of an atom of each of its ingredients, and is converted by water to muriate of soda, it is evident that the salt when in this state must contain

1 atom of muriatic acid	46.25 or	54.63
1 atom of soda	40.	45.37
and its atom weight will be	86.25	100

When 1 of sea salt is mixed with 2 of ice, or of snow, there is an immediate liquefaction and solution of the salt, so that both becoming fluid, there is a great reduction of temperature. This is the mixture employed by Fahrenheit in procuring what he supposed to be the degree of absolute cold, and at which he fixed the beginning of his scale. The temperature is not however 0, as he imagined, but —4, (p. 99.) It is the mixture also used by confectioners in making ice creams, of course there is little or no waste of the salt, for on evaporating the so-

lution, it is obtained sufficiently pure for the same purpose.

Sea salt is decomposed by the acids. By far the most important action is with oil of vitriol, as by means of it muriatic acid is disengaged, and hence the method of preparing it. Different processes are followed, according as the gaseous or common liquid acid is required.

Before preparing either, it is better to expose the salt to heat, to free it of its extraneous moisture, and by which also any vegetable matter and nitre it may contain are destroyed. For procuring gaseous muriatic acid, it is necessary to employ a mercurial trough; or, if we wish to collect it in considerable quantity, it may be done by the displacement of the air of the receivers. For this purpose equal parts of dried salt and oil of vitriol are put into the retort, (1st cut, p. 315.) and a slight heat applied, by which the gas comes off; and, by allowing it to escape for a little from the mouth of the bottle, we get this nearly full, the acid being sufficiently pure for most purposes. If more bottles than one are required, having taken away the first, another may be put in its place, and to prevent the gas from escaping after they are removed, a little lute (4 wax, 2 resin) may be laid along the stopper, by means of a hot wire.

In preparing the liquid acid, it is necessary, with the view of moderating the action, to dilute the oil of vitriol; but as heat is disengaged during the union of the acid and water, the mixture must be allowed to cool before it is poured on the salt. The proportions ordered by the Edinburgh Pharmacopœia, are,

Dried sea salt,
Sulphuric acid,
Water,—of each two pounds.

Having mixed eight ounces of the water with the sulphuric acid, put the remainder into the receiver, and when the diluted acid is cold, pour it on the salt in the retort, and apply heat. The apparatus to be used may be the same as that for preparing the gaseous acid, the

water being put into the bottle.—Or a common retort and receiver may be employed; and, in this case, after waiting a little to allow the air of the apparatus to be expelled, they must be luted together with pipe-clay. In using a small apparatus, heat may be applied by means of a lamp or chauffer; but when large retorts are employed, a furnace and sand bath are necessary, and the heat must be kept up as long as acid distils over. In preparing the liquid acid, by the process described, the retort ought not to be more than half full, lest the mixture should boil over; and the receiver must be kept cool, in the first method, by putting it into a basin of ice and water, and in the latter, by a stream of water, having previously covered it with a piece of paper or cloth, to diffuse it over its surface, and accelerate the evaporation.

If a retort, without a tubulure, be employed, the diluted acid must be poured in through a funnelled tube, to prevent any of it getting on the neck, and mixing with the muriatic acid that comes off.

In the decomposition of sea salt by oil of vitriol, whether we are procuring the gaseous or liquid acid, the salt, if considered a chlorid of sodium, is decomposed by the water, the hydrogen and chlorine uniting to form muriatic acid, and the oxigen and sodium, soda, which enters into union with the sulphuric, and remains in the retort, while the acid gas is disengaged, and coming in contact with the water in the receiver, is absorbed. If the salt be supposed muriate of soda, the sulphuric acid and alkali combine, while the muriatic and water come off together.—For, according to the old opinion with respect to the composition of chlorine, muriatic acid gas is supposed to contain water as one of its ingredients.

The liquid acid thus prepared, should be of sp. gr. about 1170; and, if pure, it is transparent and colourless; but that of commerce is generally of a brownish tinge, from its containing a little iron, derived from its acting on the vessel in which it is prepared. The residuum in

the retort, consisting of sulphuric acid and soda, is partly in the state of bi-sulphate, because a larger quantity of acid is used than is necessary for the neutralization of the alkali: still, however, there is not sufficient to convert the whole of it into this state, nor is it actually necessary; for, keeping them in atomic proportions, 75 of chlorid of sodium are equivalent to 40 of soda; which, supposing it to unite with two atoms of sulphuric acid, would require 122.5 of oil of vitriol, which contains 100, or 2 atoms of real acid. And as

$$75 : 122.5 : : 100 : 163,$$

so that, instead of equal proportions, 2 to 3, or nearly so, should be used. There is no absolute necessity, however, for employing excess of acid, for 1 atom of oil of vitriol is sufficient to decompose 1 of salt.

1 atom oil of vitriol = { 1 atom s. acid; 1 atom water = { 1 oxigen; 1 hydrogen

1 atom chlorid = { 1 chlorine; 1 sodium

so that, when decomposed, they become

1 atom muriatic acid = { 1 chlorine; 1 hydrogen

1 atom sulph. soda = { 1 sulph. acid; 1 soda = { 1 oxigen; 1 sodium

61.25 of oil of vitriol should therefore be sufficient to decompose 75 of salt; but it is supposed, that by using equal weights, the decomposition is more effectually secured, and the acid gas more easily expelled.

The residue in the retort is employed, as already noticed, in the preparation of neutral sulphate of soda, (p. 410.)

It was formerly mentioned, that muriatic acid is employed for purifying apartments, and for preventing contagion, (p. 334.) It is owing to the ease with which sea salt gives off its acid, that it is used for this purpose. The process is a very simple one: Into a tea cup or saucer, heated by holding it near a fire, a little sea

salt is put, and on it is poured about an equal quantity of oil of vitriol; which instantly unites with the soda, and disengages the muriatic acid. Should the apartment be large, it is necessary to have several vessels; and in this instance, it is best to employ soup plates, and place them on warm bricks.

Sea salt is perhaps one of the most abundant productions of nature; it is the principal ingredient in the residue procured by the evaporation of sea water, which contains about 3 per cent. of saline matter, 3-4ths of which are muriate of soda. It is likewise found in immense quantity in the bowels of the earth, as in the mines of Cheshire and Poland; and in some countries there are mountains almost entirely composed of it, a remarkable instance of which is in Cordova in Spain. When obtained from sea water, it is called *sea salt;* when got from other sources, it is termed *rock salt.* For procuring it from sea water, different processes are followed, according to the temperature of the place. It is well known, that when water, holding a salt in solution, is frozen, it deposits the whole of the salt; thus, the ice found in the polar regions, when melted, affords pure water. In cold countries, advantage is taken of this. The sea water is received into large shallow pits, in which most of it is frozen, and deposits the salt, so that the fluid beneath contains a much greater quantity than before. The ice is therefore broken, and the fluid evaporated, by which its salt is obtained. In warm climates, sea water is likewise collected in pits, which communicate with each other. When that in the first is made sufficiently strong by spontaneous evaporation, it is drawn into the second, and so on successively, till it arrives at the last, in which it is nearly a saturated solution; of course, by farther evaporation, the salt is deposited. In this country, sea salt is obtained by artificial, aided by spontaneous evaporation. For this purpose, the water is received into a large reservoir, from which it is constantly evaporating, and after this, is pumped into shallow pans, under which a strong fire is applied.

As the fluid is evaporated, the salt is gradually formed on the surface, and falls to the bottom, from which it is raked out, and put into baskets to drain. The saline matter obtained by these different processes, is not pure muriate of soda; it contains other salts, which give it a disagreeable taste, and render it unfit for many purposes for which, when pure, it is so much prized; different methods have therefore been followed for purifying it, the principal of which is that recommended by Lord Dundonald, founded on the fact, that it is not more soluble in boiling than in cold water, while the reverse is the case with the other substances with which it is mixed. A saturated solution of the saline matter is made at a natural temperature, and after being brought to a boiling heat, is poured on another portion of salt, placed in a conical vessel, with the point down, and having a small opening in it. As the impurities are more soluble in warm than in cold water, more of them is dissolved, but there is no action on the muriate of soda, so that, by repeated washings in this way, nearly the whole is removed. Still, however, the salt is not quite pure, and hence the preference given to rock salt, at least for certain purposes, as it contains so little of the foreign ingredients; indeed, in some places, it is almost free from them. When rock salt is not pure, after being bruised, it is dissolved, and the solution filtered and evaporated, by which muriate of soda is procured.

Sea salt, besides its use as a seasoning to food, is employed largely in the arts. Its use in generating cold, and in preparing muriatic acid, has been already described. From its power of preventing putrefaction, it is used in preserving meat, fish, and butter. It is employed in the manufacture of pottery, for giving a glazing to some kinds of earthenware, and in the making of glass and soap, to the latter of which it imparts hardness.

Perhaps the most important process carried on with it, is decomposing it, to make it yield soda. This was at one time carried on by the addition of litharge, a compound of oxigen and lead, which unites with the muria-

tic acid, and sets the soda free; but it has been abandoned as unprofitable. The only method now followed, is to convert it, by the addition of sulphuric acid, into sulphate of soda, and afterwards to decompose the sulphate; and the residuum of the process for preparing muriatic acid, is commonly employed for this purpose. It is mixed with charcoal and chalk, or lime, and subjected to a strong heat for some hours, by which the sulphuric acid is destroyed, the charcoal uniting with its oxigen to form carbonic acid, which is left combined with the soda, while the sulphur and lime form a sulphuret, so that, by dissolving the product, filtering, and evaporating, crystals of carbonate of soda are obtained. They are not, however, pure, but they are sufficiently so for most of the purposes to which they are applied. It is in this way that a great deal of the soda now used by soap-makers and bleachers is prepared.

Muriate of Ammonia.

Muriate of ammonia, commonly called *Sal Ammoniac*, has been long known and in use in the arts. As generally obtained, it is in large cakes of a semicircular form, owing to the figure of the vessel in which it is prepared. It is very tough, and reduced to powder with great difficulty.

It requires 3.25 of cold, and about its own weight of boiling water, to dissolve it, and during solution there is a fall of temperature.

When subjected to heat, it sublimes, and is again condensed, unchanged in its properties, on the cool part of the apparatus.

When exposed to the atmosphere, it becomes moist.

The composition of muriate of ammonia is easily determined. When equal volumes of muriatic acid and ammonia gases are mixed, the whole is condensed in the form of a white powder, so that their proportions must be as their specific gravities; that is, 1284 to 590;

and as 1284 : 590 : : 46.25 : 21.25;

so that it is a compound of

1 atom of acid,	46.25	or	69
1 atom of ammonia,	21.25		31
and its atom will be	68.5		100

The salt of commerce contains, however, water of crystallization, according to Berzelius, not less than 19 per cent.; but as this is not in atomic proportion, there must either be some inaccuracy in the experiments by which it has been determined, or the water must be considered not in chemical combination with the salt.

Muriate of ammonia is decomposed by some of the acids. Perhaps the most important decomposition is with nitric, by which an impure aqua regia is formed, and which is much employed in the arts. It is prepared by putting 3 parts of the powder of the salt into 1 of acid, in a flask, and applying a very slight heat, till the whole is dissolved. In this case, part of the nitric unites with the ammonia, and sets free muriatic acid, which acts on the rest of the other, as when the pure acids are used, *(see p. 333.)* so that the only difference in the product is its containing, besides aqua regia, a little of the compound formed by the union of the ammonia and nitric acid, but which is not at all injurious in the processes in which it is used.

It has been already mentioned, (p. 98.) that sal ammoniac generates cold during solution in water; if it be mixed with an equal quantity of nitre, both reduced to powder, and dissolved, the cold becomes still more intense. The proper proportions are 4 of the mixture to 5 of water, and there is no waste of the materials, because the product, which is merely a solution of the salts, may be procured by boiling to dryness, and will, after being powdered, answer for the same purpose. Being therefore economical, when ice cannot be procured, it is much employed for cooling receivers into which vapours are to be condensed, during distillation, and for other purposes of a similar nature.

Sal ammoniac was first procured from the dung of animals, a process long carried on in Egypt. It is now, however, prepared by the decomposition of substances containing its ingredients. The method formerly practised by the late Dr Hutton, consisted in adding oil of vitriol to soot, filtering the mixture, and evaporating to dryness. The residuum was then mixed with sea salt, subjected to heat in a close vessel, to which a top was adapted, and into which sal ammoniac was sublimed and condensed. Coal, when burned, yields a considerable quantity of ammonia, formed by the union of hydrogen and nitrogen, which exist in it, so that, when sulphuric acid is added to soot, it combines with the alkali, and forms a sulphate, which, when mixed with sea salt, undergoes decomposition, and muriate of ammonia and sulphate of soda are the products.

Another mode of preparing sal ammoniac, is by the decomposition of the ammoniacal fluid given off during the preparation of coal gas, and which is collected in a particular part of the apparatus destined for that purpose. *(See Coal.)* It is a hydro-sulphate of ammonia, so that, when mixed with sulphuric acid, it becomes a sulphate, and is then decomposed by sea salt, as already described. In some places, muriate of ammonia is prepared by the direct union of its ingredients, the alkali being procured by the decomposition of animal matter, which, when heated, gives off ammonia, by the union of part of the hydrogen and nitrogen always existing in it. For this purpose, old bones, horns, hoofs, &c. are subjected to heat in a retort, and the ammonia, disengaged, is conveyed into a large leaden chamber, into which also is thrown muriatic acid gas, derived from the decomposition, either of sea salt or of the *bittern* of sea water, and which contains muriate of magnesia.

Sal ammoniac is employed abundantly in the arts. Its use in preparing aqua regia, and for generating cold, has been already noticed. It is used in soldering some of the metals, and in tinning iron and copper, a layer of

the salt being put on the metals, to prevent the action of the air at the temperature to which they are subjected. It is used also by dyers in preparing some of their dyes, and it is decomposed so as to make it yield its alkali. *(See Lime.)*

Hydriodates.

The *hydriodates of potassa* and *soda* are formed in the process for procuring the iodates, (p. 419.) But with their properties we are little acquainted. Like the other hydr-acid salts, when subjected to heat, they undergo decomposition, and become iodurets.

Hydriodate of ammonia is formed by the direct union of the ingredients.

When detailing the properties of carbonate of soda, it was mentioned that kelp, from which the carbonate is frequently procured, contains iodine. It exists in it as a hydriodate, or rather ioduret, by the decomposition of which it is always obtained. For preparing it, the saline matter left on the evaporation of the solution of kelp, and from which the free alkali has been removed by the oil in the manufacture of soap, is put along with an equal quantity of sulphuric acid into a retort, to which a receiver is adapted. On the application of a slight heat, iodine vapour and sulphurous acid come over, the latter of which escapes, while the former is condensed in the cool part of the apparatus, in dark shining scales. To purify it, it is again placed into a retort, with a little water, and distilled off, the water being used with the view of retaining any adhering acid.

In this experiment, the ioduret in the kelp salt becomes hydriodate, by decomposing the water of the oil of vitriol, upon which the sulphuric acid then acts. Part of it unites with the alkali, and disengages hydriodic acid, but which is also decomposed, its hydrogen uniting with oxigen from the remainder of the sulphuric, to form water, and thus liberating iodine and sulphurous acid.

As the sulphurous acid in this process is very offensive,

and apt to carry off some of the iodine with it, it has been proposed to prevent its formation, by presenting to the hydriodic acid a substance which parts with its oxigen easily, and for this purpose, the metallic compound called black oxid of manganese is used, which, when acted on by sulphuric acid, with the aid of heat, gives off oxigen. A mixture of 1 part of this oxid, and 2 of each of the other substances, is placed into the retort, and heat applied, the hydriodic acid from the salt, and oxigen from the oxid, coming off together; the latter unites with the hydrogen of the former, and produces water, while the iodine escapes in vapour, and is condensed in the cool part of the apparatus.

Fluates.

Fluoric unites with the alkalies, and forms a class of salts called *fluates*, the properties of which have not been minutely examined.

Fluate of Potassa, prepared by the saturation of the acid with potassa, has a sharp taste, and soluble in water. It undergoes watery fusion, and is deliquescent. When the solution is evaporated to dryness, the salt probably becomes fluorid of potassium. It is decomposed by sulphuric acid, which unites with the base, and disengages the acid.

Fluate of soda, formed by a similar process, is also soluble; but it decrepitates by heat, and does not suffer any change on exposure to air. It is also decomposed by sulphuric acid.

Fluate of ammonia is also soluble, and, during its solution, undergoes decomposition, owing to the expulsion of part of the ammonia. When heat is applied to the dry salt, it is volatilized.

Hydro-Cyanates.

The salts formed by the union of hydro-cyanic acid and the alkalies, called *hydro-cyanates*, are kept with very

great difficulty, being so easily decomposed. They are all formed by the neutralization of the acid by the alkalies.

Hydro-cyanate of potassa is soluble in water, its solution changing blues to green. It is decomposed by acids, which unite with its alkali, and set hydro-cyanic acid free. When exposed to heat, it undergoes the same change as the muriate, the hydrogen of the acid and oxigen of the potassa uniting to form water, while the cyanogen and potassium yield cyanuret, and which, when thrown into water, again becomes hydro-cyanate.

Hydro-cyanate of soda is similar in its properties to that of potass.

Hydro-cyanate of ammonia is also soluble, and may be obtained from its solution in crystals, which are so volatile, that at a temperature of 72, the vapour rising from them will support a column of mercury of about 15 inches, and at 97, one of about 30, so that it is equal to the pressure of the air itself. This hydro-cyanate may also be obtained, by subjecting Prussian blue to heat, in a small retort, by which slender crystals are deposited in the cool part of the apparatus.

Hydro-Sulpho-Cyanates.

The hydro-sulpho-cyanates are in general prepared by the decomposition of the salt called Ferro-cyanate, or Prussiate of Potassa, and which contains an acid, having cyanogen and iron as its base, in union with hydrogen. For this purpose equal weights of flowers of sulphur and the salt are exposed to heat, by which the mixture is fused and inflamed, and, having allowed the combustion to cease, it is to be kept on the fire for two or three minutes longer, and well stirred. It is then sulpho-cyanate, or rather hydro-sulpho-cyanate, the sulphur having combined, partly with the iron, to form a sulphuret, and partly with the cyanogen and hydrogen, to produce hydro-sulpho-cyanic acid. According to some, however, the substance obtained in this process is not a compound

salt, but a sulpho-cyanuret of potassium, and becomes a salt when thrown into water, by the oxigen uniting with the potassium, and the hydrogen with the sulpho-cyanuret; if so, the body employed in its preparation must be considered a ferro-cyanuret of potassium, so that the sulphur will combine partly with iron, partly with the cyanogen, and that produced by the latter will be left in union with the metallic base. The solution of the sulpho-cyanuret, of course, containing a hydro-sulpho-cyanate, yields, on evaporation, transparent crystals, which are very deliquescent. When acted on by acids, it is decomposed, and hence the method of procuring its acid. For this purpose a concentrated solution of the salt is mixed with as much sulphuric acid as will saturate the potassa, and the mixture being put into a retort, is subjected to distillation, by which hydro-sulpho-cyanic acid comes off, and may be condensed in a cool receiver.

The hydro-sulpho-cyanate contains an atom of each of its ingredients; and as there is an atom of oxigen in the oxid, and of hydrogen in the acid, hence, when dried, the latter forms water, leaving sulpho-cyanuret of potassium.

Hydro-Xanthates.

It has been already mentioned, (p. 283.) that when sulphuret of carbon is treated with an alcoholic solution of potassa, the alkali is found to be united to an acid containing hydrogen in union with sulphur and carbon as a base, and which has been called xanthogen, from the yellow colour of some of its compounds.—Hence the method of forming hydro-xanthates. For this purpose the sulphuret is added, in small successive portions, to the alcoholic fluid, till the whole of the potassa is neutralized, after which it may be made to yield crystals, either by reducing its temperature, or by evaporation under an exhausted receiver along with sulphuric acid.

The hydro-xanthate thus prepared, is in needle-formed colourless crystals, but which become yellow by exposure

to air. It has a peculiar odour, and a sulphureous taste. It is soluble in water, affording a solution at first transparent, but soon becoming turbid, from the decomposition of part of the acid.

When subjected to heat in close vessels, it is decomposed, an oily fluid being distilled over, along with a gaseous matter, consisting of carbonic acid and sulphuretted hydrogen. When heated in air it is kindled, and burns with a bluish flame.

On the addition of diluted sulphuric or muriatic acid, a heavy oily-looking substance is deposited, which is hydro-xanthic acid; and hence the method of preparing it, merely by the addition of the diluted acid, till the alkali is saturated with it.

SECTION IX.

SUBSTANCES FORMING SALIFIABLE BASES, COMMONLY CALLED EARTHS.

The earths are solid brittle substances, white, inodorous, and in general insipid. They are not affected by heat, unless very intense. With the exception of two, they are sparingly soluble; indeed, some are insoluble. They are not inflammable. Their sp. gr. never exceeds 4500.

The greatest part of the surface of the globe consists of the earths; they are therefore of peculiar interest, not only from their abundance, but from their use in agriculture, medicine, and the arts. When we take a superficial view of the fossils composing the crust of the globe, we perceive an immense variety; but when we examine them chemically, we find that the diversity is occasioned by the combination of few substances. The earthy bodies do not exceed eleven in number, and of these, six are rarely met with; so that, by the union of five, almost all fossils are produced.

The earths are, lime, magnesia, baryta, strontia, alumina, silica, yttria, zirconia, and glucina, to which have been lately added, lithia and thorina. They have been divided into two classes, the *alkaline earths*, and the *earths proper*,—the former so called because they are soluble in

water, and their solution changes vegetable blues to green,—the latter, because they are insoluble.

The earths, like the fixed alkalies, were long considered simple bodies. After the discovery of the composition of the latter, Sir H. Davy was naturally led to suppose that the former might be similar in their composition ;—that they might be compounds of a metallic base and oxigen, a supposition which has been verified by experiment. The metallic bases of some of them have been obtained in their separate state, and, though those of the others have not yet been got pure, yet the results of their analyses prove, beyond doubt, that in their composition they are the same.

CALCIUM.

After Sir H. Davy had discovered the compound nature of potassa and soda, he endeavoured by a similar process to ascertain whether lime was, like them, composed of oxigen and a metallic base. By subjecting it to the action of a powerful galvanic battery, it seemed to be decomposed. About the same time Berzelius and Pontin succeeded in decomposing it, by negatively electrifying it while in contact with mercury, by which the metallic base was procured; and by this process, slightly modified, Davy succeeded in obtaining a sufficient quantity to enable him to ascertain a few of its properties. He made a thick paste of lime and red oxid of mercury, and placed it on a platinum cup, connected with the positive end of the trough. A cavity was then made on its surface, into which a globule of mercury was poured, and by connecting this with the wire from the opposite end, an amalgam was obtained, consisting of the mercury and the metallic base of the lime, and which, when heated in tubes with naphtha, gave off the mercury, and left the other pure. To this the name of *calcium* has been given.

Calcium was white like silver ; when exposed to air, it

attracted oxigen, and formed lime. When heated in air, it burned with brilliancy, also forming lime.

According to the experiments of Berzelius, lime is composed of

calcium, - - - -	100
oxigen, - - - -	38.57

From the experiments of Dr Thomson, the atomic weight of calcium is 25,

and as 100 : 38.57 : : 25 : 9.6;

so nearly 10, that we may consider lime as composed of

1 atom calcium, - - -	25
1 atom oxigen, - - -	10
and its atomic weight	35

Lime.

Lime is by far the most useful and abundant of the earths. When pure, it is white, moderately hard, and brittle. It has a hot pungent taste, and corrodes powerfully both animal and vegetable matter. Its sp. gr. is 2300. When exposed to the heat of a powerful furnace, it is not fused; but it may be liquefied by the oxi-hydrogen blowpipe, and it then forms a transparent glass.

It has a very powerful attraction for water, absorbing it with great avidity, and the action between them is peculiar. When water is poured on it, it is absorbed with a hissing noise, the lime becomes warm, swells, and at last falls down in powder; at the same time heat is generated, sufficient to drive off part of the fluid in vapour. If the quantity is considerable, the heat becomes very high, as there are well-authenticated instances of ships having been set on fire by the lime with which they were loaded having absorbed water, owing to the vessel being leaky. If the process be conducted in the dark, light is also emitted. The evolution of heat, and the pulverisation of the lime, are easily accounted for. The water, by uniting with the earth, becomes solid, and of course gives forth its

latent caloric, and as the temperature is sufficient to form vapour, the expansive force of this separates the particles, just as in common cases of decrepitation. This process is called the *slaking* of lime; the compound is *slaked lime*. It is of course a *hydrate*.

According to Dalton, 100 of lime absorb, during slaking, 33.3, and according to Berzelius, 32 of water, the last of which we are to consider as nearest the truth, for if the hydrate be a chemical compound, the ingredients must be in atomic proportions.

And as 100 : 32 : : 35 : 11.20;

so nearly 11.25, that we must consider the hydrate to consist of

1 atom of lime,	-	35
and 1 atom of water,	-	11.25
making 100 to absorb	-	32.14.

Though lime has a powerful affinity for water, it is but sparingly soluble, and, what is very remarkable, it is more so in cold than in warm water. According to Dalton, at 60 it requires 778, and according to Philips 752, for solution. Dalton states that water at 60 dissolves 1-788th of pure lime, and 1-584th of slaked lime, but at 212, only 1-1270th of the former, and 1-952d of the latter. Hence, if a cold solution be boiled, excluded from air, minute particles of lime are deposited.

It is evident from this, that crystals cannot be obtained by the evaporation of a warm solution, but Gay Lussac succeeded in procuring them by keeping lime water under an exhausted receiver along with sulphuric acid. They were in the form of minute hexaedrons, and consisted of lime with water of crystallization in the same proportions as those of slaked earth.

Lime water is transparent and colourless. It has a styptic taste, and, like the alkaline solutions, has the power of changing vegetable blues to green, and hence it is that lime has been considered an *alkaline earth*.

When lime water is exposed to air, it very soon acquires a crust on its surface, and if the fluid be shaken occasionally, the whole of the earth is deposited in the

form of carbonate, owing to the absorption of carbonic acid from the atmosphere. That the lime is removed, is proved by the loss of taste, and by the want of action with vegetable colours. Hence the necessity of keeping the solution in well-stoppered bottles. The best method of having a store of lime water, is to put a considerable quantity of slaked lime into a large bottle, which must be always kept full, water being poured in when any of the solution is taken out, by which means, should any of the earth be deposited in the form of carbonate, the water can dissolve more, and thus remain always saturated.

Lime itself, when exposed to the atmosphere, absorbs moisture and carbonic acid, by which it is gradually slaked and converted to carbonate; and hence also the necessity of keeping it excluded as much as possible from air.

The action between lime and some of the simple substances is important, more particularly with phosphorus, sulphur, and chlorine.

Phosphuret of Calcium.

When phosphorus is made to act on lime in the dry way, a dark-coloured compound is formed, commonly called *Phosphuret of Lime*, but which is probably a mixture of phosphate of lime and phosphuret of calcium.

For preparing it, a green glass tube, about two feet in length, and half an inch in diameter, shut at one end, is coated with clay and sand. At the shut end about a drachm of phosphorus is placed, and over this some pieces of lime, which must be brought to a red heat, by passing the tube through a chauffer, the phosphorus at the same time being kept cool. When properly heated, the phosphorus is then to be melted, and made to pass in vapour over the hot earth, by which the action takes place, and the phosphuret is formed. When cold, it ought to be removed, and kept in a well-corked phial.

In this experiment, it is probable that the lime is decomposed, part of the phosphorus uniting with its oxigen to form an acid, while the remainder combines with the calciumto generate a phosphuret.

The phosphuret thus obtained, is of a dark brown colour, and has a peculiar odour. The action between it and water is remarkable. When thrown into it, bubbles of gas are disengaged, which, the moment they escape into the air, are inflamed; they are therefore phosphuretted hydrogen, the oxigen of the water having united with the calcium, and the hydrogen with the phosphorus.

The action between phosphorus and lime, when water is present, is also important, phosphuretted hydrogen gas being evolved; and hence the method generally followed in procuring it. For this purpose, the bulb of a small retort, with a narrow neck, is filled with a thin paste of lime and water, and into it a few pieces of phosphorus are afterwards introduced, and thrust into the mixture; on the application of heat, the mouth of the retort being kept in water, bubbles of gas begin to make their escape, and after these have continued to flow for some time, they may be collected in a small jar, or they may be allowed to issue from the water into the air, by which they are instantly inflamed. In this case, the water undergoing decomposition, gives its oxigen to part of the phosphorus to form an acid, which is left in union with the lime, and its hydrogen to another part to form phosphuretted hydrogen.

Sulphur and Lime.

Sulphur does not act with lime when dry, but if moisture be present, or if they be boiled with water, there is a decomposition and formation of compounds with acids of sulphur, generated by its entering into union with the ingredients of the water. They will be described along with the salts of lime.

Chlorine and Lime.

The action of chlorine with lime is important. When it is passed over it at a red heat, oxigen gas is disengaged, and chlorid of calcium formed, for each volume of the former absorbed, half a volume of the latter being evolved. The chlorid of calcium thus formed, is com-

posed of 64 chlorine, and 36 calcium, and, like others already described, becomes muriate when thrown into water.

When chlorine is passed through slaked lime, it is gradually absorbed, and a powder is produced, long known by the name of *oxi-muriate of lime*, and now much employed in bleaching; but different statements have been given of its composition, some supposing it a mixture of chlorid of calcium with muriate of lime, others a compound of lime and chlorine, and therefore a chlorid.

It varies considerably, according to the manufactory from which it is procured, so that it would appear not to be, strictly speaking, a chemical compound or chlorid, but merely a powder holding chlorine gas in a state of mechanical absorption; an opinion which seems strengthened by the facts, that when slightly heated, chlorine is disengaged, or when exposed to air but for a short time, its properties are completely altered. One sample analyzed by Dalton, contained

23 chlorine,
38 lime,
39 water.

100

This substance, when thrown into water, is partly dissolved. The insoluble matter consists almost entirely of lime. The solution, which is transparent and colourless, possesses the power of destroying colour, though by no means so much so as that of chlorine itself. If, for instance, a little of it be added to any vegetable infusion, the colour very soon disappears. The same is the case with those of the animal kingdom, as with infusion of cochineal. When the colour is imparted to cloth, it is also banished by the solution, as may be shewn by putting some pieces of printed calico into it, and leaving them there for some hours, for in this instance, a longer time is required, than when the infusion is used. It is from this power of destroying colour, that it is now so much employed in bleaching.

Before proceeding to describe the process as now conducted, it may not be uninteresting to detail the steps according to the old method, not only because in many parts they agree, but as it affords a good example of the great improvement which some of the arts have received from chemistry.

The first part of the process, according to the old mode, was the STEEPING, which consisted in keeping the cloth for some days in cold water, or in a very weak solution of potash, so that the impurities might be loosened and dissolved, the potash acting on the greasy matter, and forming with it a kind of soap, after which it was well washed. The next operation was BUCKING, or boiling the goods in an alkaline solution, or what the bleachers call a *ley*, after which they were exposed on the ground for two or three weeks, and again bucked, washed, and laid on the green, these being in general repeated four or five different times, and the ley made gradually weaker. After the cloth had been subjected to these different processes, it was next submitted to that of *souring*, which consisted in soaking it in milk that had been allowed to become sour, where it remained for two or three weeks, after which it was removed, and again subjected to the processes described, till it appeared to be quite cleaned, in the last washing, soap being generally used, by which this was more easily accomplished. It has been already mentioned, that the alkali, in the process of bucking, loosened the foreign matter. The souring, containing a small quantity of acid, destroyed the properties of the alkali, by combining with it, and thus prevented it from acting on the cloth; at the same time, by washing between each operation, any excess of alkali or acid was removed, and it was thus left in a state fit for being whitened by exposure to air. In this last part of the process, it was supposed to be the oxigen of the atmosphere that acted on the colouring matter, and imparted whiteness.

The bleaching process now described, was extremely

tedious. When begun in March, it was seldom finished till September, and when the web was not sent till about May, it was only half bleached that year, and finished in the spring of the succeeding. About the middle of the last century, a great improvement was introduced, by substituting for sour milk, very much diluted oil of vitriol, by which the process was shortened; indeed, it was completed in about half the time, for each souring did not require more than from 12 to 24 hours, whereas that with milk continued for several weeks. The most important improvement, however, was the introduction of chlorine. Soon after this substance was discovered, Berthollet shewed that it might be used with the utmost success in bleaching, and it was shortly afterwards applied to this purpose in Great Britain. It was first used in the gaseous form, the cloth being suspended in apartments filled with it, but for which its solution in water was soon substituted.

Though bleaching had thus received a very great improvement, with respect to the shortening of time and diminution of labour, it was found that the newly discovered substance proved extremely injurious to the workmen; other methods of using it were accordingly tried, the first of which was that of combining it with solution of potass, or lime, which were equally efficacious, without being in the least noxious, or even disagreeable; but it still possessed a disadvantage, the inconvenience of conveying it from the manufactory to the bleaching ground. This was, however, soon obviated by Mr Tennant of Glasgow, who discovered a mode of combining it with lime in its dry state, in which form it is easily transported in barrels. The bleaching compound now used, and generally called by bleachers *oxi-muriate of lime*, is prepared merely by passing the gas through slaked lime kept in vessels, in which it is constantly agitated by machinery. After it ceases to be absorbed, the product is removed, put into barrels, and as much as possible excluded from air.

In the process of bleaching as now conducted, the

cloth is submitted to the previous steps of bucking and souring, four or five different times, being well washed after each operation. It is then put into a solution of the bleaching compound, where it remains for some time, after which it is washed, and again submitted to the process of souring and steeping. This immersion into the bleaching fluid is repeated several times, according to the nature of the cloth, being soured, steeped, and washed, after each immersion. When these are finished, the cloth acquires a yellow tinge, but this is easily banished, by exposing it on the ground for a few days, and again boiling it for a short time in a weak solution of potash and soap.

Since the introduction of the bleaching compound, the whole process, even with large webs, never requires more than five weeks, and a small piece of cloth may be finished in a few days. Besides this very great improvement, the new process has other advantages; the cloth is not so apt to be destroyed, for, in the old mode, the repeated operations to which it was subjected tended to weaken it, whereas in this, the impurities only are removed.

The process of bleaching now described, is that practised with linen goods; with cotton there is no necessity for the latter part of it, as it does not acquire the yellow tinge by the use of the bleaching compound.

The principal circumstance to be attended to in bleaching according to the new process, is to take care that the goods are well washed after each operation, and that the solution of the bleaching substance is not too strong, as it is then apt to injure the cloth. To ascertain this, bleachers have in general what is called a *test fluid*, which is merely a solution of indigo in weak oil of vitriol. In preparing the bleaching fluid, it is made of such strength, that a certain quantity of it must destroy the colour of a known weight of the indigo solution. It is with the same view also, that weavers often run a coloured thread along the end of their goods, by which they know if the bleaching fluid has been of proper strength, for, when

properly prepared, it ought to bleach without destroying the colour of the thread.

Before finishing this subject, it may here be remarked, that a solution of the bleaching substance is very efficacious for removing the yellow tinge, which linens always acquire by being worn. For this purpose, they are kept for a few days in a weak solution of it, and then well washed, the solution being prepared by dissolving a tea-spoonful in a choppin of water. It is also much employed for taking out ink spots from cloth, or paper. This is done by applying the solution, by means of a hair pencil, to the part soiled, and after it has remained on for some time, washing it off with cold water. Should the first process not succeed, it must be repeated, taking care to wash well after each application. It may even be applied to printed paper, or copper-plate impressions, as it does not act on the inks used by printers and engravers.

Fluorid of Calcium.

The mineral called fluor, or Derbyshire spar, was long considered a compound of fluoric acid and lime, in the proportions of 26 of acid, and 71 of base. Since the views of Davy, with respect to the nature of chlorine, have been advanced, it is now supposed to consist of *fluorine* and *calcium*, in the proportion of

fluorine,	47.37
calcium,	52.63

Fluor spar is an abundant natural production, occurring both amorphous and crystallized. The crystals which are of different colours, as blue, green, purple, and yellow, are cubes, but they vary considerably, owing to truncation and bevelment. Its sp. gr. is 3200. When gently heated, it becomes phosphorescent, and different coloured lights are emitted, according to that of the spar. When the heat to which it is exposed is strong, it is fused, and becomes a transparent glass.

The most important action of this substance is with

sulphuric acid, by which it is decomposed, and fluoric acid set free, and hence the method of procuring it.

For this purpose, it is necessary to employ metallic apparatus, as of silver or lead, because when glass is used, the siliceous matter is dissolved by the acid. The spar reduced to powder, is put into the retort, and two parts of oil of vitriol poured on it. A receiver is adapted and kept cool by ice and water, and on the application of heat the acid gas comes off, and is condensed. In this instance, if we suppose the spar to be fluate of lime, the sulphuric acid and lime form a sulphate, while the fluoric acid with the water of the oil of vitriol come off; but on the supposition that it is fluorid of calcium, the action becomes more complicated. Between the fluorid and water of the oil of vitriol, there is a double decomposition, the oxigen uniting with the calcium, and the hydrogen with the fluorine; the one to form lime, and the other fluoric acid, the former of which unites with the sulphuric acid, while the latter is disengaged, of course free from water.

Fluorid of calcium is found also in minute quantity in bones, and in the enamel of teeth.

Salts of Lime.

Lime unites with the acids, and forms some very interesting compounds, more particularly with carbonic, phosphoric, sulphuric, and muriatic acids.

Carbonate of Lime.

When carbonic acid water, or a stream of gas, is passed through lime water, a white precipitate of carbonate is formed. Though the carbonate can thus be procured by the direct union of its ingredients, it is never prepared in this way for use, being a very abundant production of nature.

Carbonate of lime was at one time supposed to be the earth in a state of purity; and as it was known to lose weight on the application of heat, it was imagined to

contain moisture, which was expelled. Various other conjectures were thrown out concerning it, till Dr Black discovered its composition. He ascertained, that besides water, a gaseous fluid was also disengaged, which, with the watery vapour, made up the loss sustained; and that, on again adding this gas to the residue, a compound similar to that subjected to analysis was formed.

Carbonate of lime is insipid, inodorous, and inert, with regard to the animal frame. Its specific gravity is 2700. It does not suffer any alteration on exposure to air. It is insoluble in water. When subjected to heat, it is decomposed, the acid is expelled, and the lime left pure; and hence the method of preparing lime on a large scale, when required for building, or for agricultural purposes. For this the limestone, broken to small pieces, is mixed with coal, and thrown into a kiln, in which a fire has been previously kindled, and the heat generated by the combustion is sufficient to drive off the whole of the acid. As the coal is consumed, the lime falls to the bottom, and is raked out through an opening below, while fresh portions of the mixture of coal and limestone are thrown in from above. In some places a sort of kiln is erected of bricks, at the bottom of which is placed straw or coal, and over this alternate layers of coal and limestone, and the whole covered with turf, leaving apertures below for the admission of air, and a vent above for the escape of smoke. The fire beneath is then kindled, and the combustion allowed to continue till the whole of the coal is consumed, by which also the carbonic acid is driven off. The lime is then taken out, and separated from the ashes.

All the acids decompose carbonate of lime; they unite with the lime, and set free the carbonic acid, and hence the method of preparing this gas; indeed, it is the one generally practised. Pieces of chalk are put into a retort, and a little muriatic acid, previously mixed with about six parts of water, is poured on them; there is an instant effervescence, and a gaseous fluid may be collected in the jar. That this is carbonic acid, is proved by putting

into it a lighted taper, which is instantly extinguished. It is in this way, also, that we know whether limestone has been properly burned, that is, whether the heat has been sufficient to expel the whole of the acid; for if recently burned lime be put into diluted muriatic acid, it will not effervesce if properly prepared. It is not to be expected, however, that the lime offered for sale should be entirely free from this; besides, by exposure to air, it will absorb it, which will cause a slight effervescence on the addition of the acid; if, however, the effervescence is great, we must infer that the burning has not been properly conducted.

The composition of carbonate of lime, given by different chemists, is very nearly the same. They all agree in making it contain about 44 per cent. of carbonic acid;

and as 56 : 44 : : 35 : 27.5,

so that it contains

1 atom of acid,	-	27.5
1 atom of lime,	-	35.
its atomic weight being		62.5

It has been already mentioned, that when carbonic acid solution is poured into lime water, a white precipitate of carbonate of lime falls. If more of the acid fluid be thrown in, the powder disappears, and a transparent colourless solution of super-carbonate is formed. This change on the lime may also be shewn by breathing through a tube into lime water, by which, owing to the disengagement of carbonic acid from the lungs, the carbonate is precipitated; and after this, by continuing the respiration, the fluid will again become transparent. When solution of super-carbonate is exposed to air, or when it is boiled, it becomes opake, owing to the expulsion of the excess of acid and precipitation of carbonate.

The alkalies have no action with carbonate of lime. Some of the compound salts, however, decompose it. When heated with muriate of ammonia, both are decomposed, and a muriate of lime and carbonate of ammonia are formed, the latter of which being volatile, is sublim-

ed; and hence a method of preparing the carbonate as ordered by the Pharmacopœia. For this purpose we are ordered to use

Muriate of ammonia, in powder, one part.

Soft carbonate of lime, (chalk), dried, two parts.

Having mixed them thoroughly, they are put into a retort, and sublimed into a cool receiver.

In this case, more carbonate of lime is ordered than is absolutely necessary for the decomposition of the muriate, yet unless this excess is used, part of the latter is apt to sublime and come over with the newly formed compound.

Carbonate of lime is a very abundant production of nature, occurring in different states, distinguished by the name of *Calcareous Fossils*. The different varieties of it do not strike fire with steel; they may be scratched with a knife, and they all effervesce on the addition of an acid. Calcareous fossils are found in strata most abundantly in the secondary. The least indurated kind is *chalk*, which composes strata of immense thickness, and often contains the remains of organic matter. When more indurated, it is called *Limestone*, in which also are found animal and vegetable matter. When it becomes still harder, it forms *marble*, of which there is a great variety, and in which also organic exuviæ occur. Carbonate of lime is found also among the primary strata, and it occurs likewise crystallized, under the name of Calcareous Spar. It is a very frequent ingredient also in mineral waters, more particularly in those in which there is a considerable quantity of carbonic acid, and from which, as the acid flies off, incrustations of carbonate are deposited. Hence the formation of *petrifactions*, for when any vegetable matter, as a piece of moss, is kept for some time in a water of this kind, the deposited carbonate adheres to it, and ultimately makes it appear as if it were converted into earthy matter. When the fluid drops from the roof of a cavern, the carbonic acid flying off, leaves the carbonate, which, adhering to the roof, gradually increases in size from the water passing along it, and it thus forms *stalactites*. The *shells* of marine animals, and

the different kinds of *marl*, are also composed of carbonate of lime.

As the different kinds of limestone vary in their composition, it is of consequence to be able, by an easy process, to ascertain the quantity of lime; and this is in general done by driving off the carbonic acid from a certain quantity of it. *(See Appendix.)*

Phosphates of Lime.

When phosphoric acid is added to lime water, or when an alkaline phosphate is mixed with a solution of any of its salts, a white precipitate of phosphate is formed. The phosphate is not, however, prepared in this way for use. It is an abundant production of nature, being the principal ingredient of bones. When these are exposed to heat, so as to burn off the animal matter, a white mass, retaining the form of the bone, is left, and which is the earthy phosphate very nearly pure. To obtain it pure, the bone ash must be reduced to fine powder, well washed with warm water, to carry off any soluble salt, and then dissolved in diluted muriatic acid. On the addition of ammonia, a white precipitate of phosphate of lime appears.

Phosphate of lime is a white tasteless substance not altered by exposure to air, and insoluble in water. It may be subjected to a high temperature, without undergoing any change, but if the heat be very violent, it becomes soft. It has no action with oxigen, nitrogen, or inflammables.

Some of the acids affect it, but the decomposition is not complete. The action with sulphuric acid is important, as by it a fluid, containing phosphoric acid, is obtained, and from which pure phosphoric acid, phosphorus, and phosphate of soda, can be procured.

The process for procuring phosphate of soda by the decomposition of burnt bones, is a pharmaceutical one.

The Edinburgh College orders

Burnt bones, in powder, ten pounds;
Sulphuric acid, six pounds.

The bones and acid are mixed in an earthen pot, and afterwards diluted with water. The mixture is then digested for some days, and after putting in more water, is strained through a linen cloth. It is next concentrated by evaporation, and solution of carbonate of soda added as long as there is any effervescence, and after again filtering and evaporating, crystals of phosphate of soda are formed.

In the first part of this process, the sulphuric acid decomposing part of the phosphate, unites with its lime, and disengages its acid, which then enters into combination with the undecomposed part, to form a soluble super-phosphate; so that, by washing the mixture, this is carried off, and on the addition of carbonate of soda, the excess of acid in the super-phosphate is saturated by soda, and converted to phosphate, while neutral phosphate of lime is precipitated; carbonic acid is of course disengaged. The solution, after filtration, yields crystals of phosphate of soda, but it is necessary to have a slight excess of alkali to favour the crystallizing process. The precipitated substance will answer for the same, or for other processes, as it is pure phosphate of lime.

If, instead of saturating the acidulous liquor with carbonate of soda, that of ammonia be employed, a phosphate of it is obtained, which, when evaporated to dryness, and exposed to a red heat, gives off its alkali, and its acid is left nearly pure. Hence a method sometimes practised for procuring this acid. It is the one alluded to in p. 303. All that is necessary is, to evaporate the solution, and expose the residue to a red heat till ammoniacal vapour ceases to come off.

When the acidulous fluid, procured by the decomposition of bones after evaporation, is heated with charcoal, the acid is deprived of its oxigen, and phosphorus is given off in vapour; and hence the method by which it is prepared. *(See p. 298.)*

Phosphate of lime is, according to Thomson, composed of an atom of each of its ingredients, and as the

atomic weights of these are the same, it contains equal proportions by weight ; that is,

1 atom acid,	35	or	50
1 atom lime,	35		50
its atom being	70		100

Besides the uses of phosphate of lime as already mentioned, it is employed in making cupels for the refining of gold and silver. It is used also in polishing metals, and for taking out greasy spots from cloth.

If, after throwing down phosphate of lime by the addition of the acid to lime water, more of the acid be added, the precipitate disappears, and a transparent solution of super-phosphate is formed, which, on evaporation, affords a white saline mass, deliquescent and soluble in water, but not in acids. It contains double the quantity of acid that exists in the neutral compound, and is therefore a *bi-phosphate.*

The acidulous fluid obtained by the decomposition of bone ash by oil of vitriol, has a still larger proportion of phosphoric acid. It is a *quadri-phosphate*, or contains four times the acid that the neutral salt does. When evaporated to dryness, a saline mass is obtained, which, when exposed to heat, forms *glacial phosphoric acid*, used, as already mentioned, for yielding phosphorus.

Sulphate of Lime.

Sulphuric acid very readily unites with lime. If a little be poured on pieces of it, recently burned, in a crucible, they unite, and with the evolution of heat sufficient to drive off part of the acid in vapour ; and hence the necessity of putting on a shade the instant that the acid is thrown in.

Sulphate of lime is not, however, prepared in this way for use. It is an abundant production of nature. It is a white insipid substance, and but sparingly soluble in water, requiring about 500, at a natural temperature, to dissolve it. The solution is transparent and colourless, and on evaporation, affords slender filamentous crys-

tals. It has no action with the simple substances, except with charcoal, by which it is decomposed at a red heat; and, provided there is no water present, *sulphuret of calcium* is formed; the action being the same as with the alkaline sulphates, the carbon uniting with the oxigen of the acid and earth.

Potassa and soda decompose it, throwing down from its solution the lime in a state of purity, while the alkaline carbonates precipitate carbonate of lime. Though the sulphate is thus easily decomposed by the alkalies mentioned, ammonia does not affect any change on it, for when added to its solution, there is no precipitation, and the same is the case with the other salts of lime.

Sulphate of lime is a natural production, known by the names of *Gypsum* and *Selenite*. Its chief source is from the neighbourhood of Paris, where it composes immense strata, and from a particular use to which it is applied, it is called *Paris Plaster*. It is in general of a pale reddish hue, the colour being communicated by some metallic matter; but is occasionally found quite white, in which state it is called *Alabaster*. Alabaster admits of a fine polish, and is often cut into ornaments, as vases and urns. Common sulphate of lime, when exposed to heat, gives off water, which it contains, and is left pure; and when thus prepared, it has a very powerful attraction for water, with which it combines, and forms a hard mass; from which property it is employed for taking impressions from moulds, and for making statues. For this purpose, it is made into a thin paste, and poured into a mould, previously besmeared with a little soap or tallow, to prevent them from adhering. It is left there till it becomes hard, and is easily removed.

Paris plaster, when mixed with lime, is also employed in forming ornaments for the ceilings of rooms, in which state it is called *stucco*. In some places, particularly where it is abundant, it is used as a top-dressing for grass lands, and it is employed as mortar instead of lime.

Hydro-Sulphate and Hydro-Sulphite.

Both sulphuretted and super-sulphuretted hydrogen unite with lime, and form compounds, the latter important from the uses to which it is applied.

Hydro-sulphate may be prepared by passing a stream of gas through milk of lime, or by throwing into water the sulphuret of calcium prepared by the decomposition of sulphate by charcoal. Like other soluble hydro-sulphates, it is decomposed by air.

A much more important compound is the hydro-sulphite, (sulphuretted hydro-sulphuret.) It is prepared by boiling in water, 2 parts of lime, and 1 of flowers of sulphur, by which a dark coloured solution is formed, containing a mixture of sulphate and hydro-sulphite ; but as the former is very sparingly soluble, the greater part of it is deposited when the fluid cools.

This solution is used for the same purposes as that of the alkaline hydro-sulphites, as in eudiometry, (p. 426.) and it is from it that precipitated sulphur is obtained. For this purpose muriatic acid is added as long as there is any precipitation, by which it unites with the lime, sulphuretted hydrogen flies off, and the excess of sulphur of the super-sulphuretted hydrogen is deposited.

Muriate of Lime.

Muriatic acid unites with lime, and forms an important compound. It may be procured in six-sided prismatic crystals, but it is usually got by the evaporation of its solution in the form of a white powder. It is very deliquescent ; owing to which it is much employed for drying gases confined over mercury, and for freeing them from moisture during their preparation, and which is done by passing them through tubes stuffed with it. It is very soluble, and during its solution generates cold. It acts with great ease on snow and ice, particularly the former ; and as there is a rapid liquefaction, the reduction of temperature is considerable ; and more particularly so, if they have been previously cooled, as when they

are kept in ice and sea salt, by which the temperature falls to —60; of course, if mercury in a tube be put into the mixture, it is very soon frozen. The residue of the operation is solution of muriate of lime; and will, on evaporation, yield it, ready again to be used for the same purpose.

When muriate of lime is heated, it undergoes watery fusion; and, by the continuation of the heat, becomes *chlorid.*

It is decomposed by some of the acids. On the addition of sulphuric acid, muriatic acid gas is disengaged. If, instead of using the dry salt, a concentrated solution is employed, the mixture becomes almost solid. For this purpose, four measures of concentrated solution must be mixed with three of diluted oil of vitriol, (equal weights acid and water,) by which the sulphuric acid unites with the lime; and in forming sulphate or Paris Plaster, combines with the water, so as almost to become solid.

The fixed alkalies, and the alkaline carbonates, decompose the muriate. It is not, however, decomposed by ammonia, and hence it is used as a test of the purity of aqua ammoniæ, for if this contain the smallest quantity of carbonic acid, it will give a precipitate on the addition of the muriate.

Muriate of lime may be prepared by the addition of the acid to the carbonate; but, as it is a residuum in different processes, it is seldom prepared in this way.

It has been already mentioned, that in the preparation of carbonate of ammonia, muriate of lime is left in the retort, but mixed with carbonate of lime. From this it is easily procured by solution, filtration, and evaporation.

Lime and Alkaline Salts.

The action of lime on some of the compound salts, is interesting, from the valuable products obtained. From its powerful attraction for carbonic acid, it easily decomposes the alkaline carbonates, depriving them of their acid, and setting the alkali free in its caustic state. Hence

the method of preparing the alkalies, and of procuring the *aqua potassæ* of the Pharmacopœia.

The process ordered by the Edinburgh College, consists in using

Lime, eight ounces;

Carbonate of potass, six ounces;

Water, twenty-eight ounces.

Twenty ounces of water are poured on the lime, and the remainder on the carbonate; and when the slaking is finished, they are mixed, and after corking the vessel, allowed to remain till cold. The mixture is then to be filtered, excluded from air, to prevent the absorption of carbonic acid. For this purpose it is thrown into a funnel, the throat of which is stuffed with a linen rag, and covered with a plate; this is to be placed into a bottle, through a cork or piece of paper, to keep it as tight as possible, so as to prevent the admission of air. After the filtration has stopped, and the mixture in the funnel become hard, water is to be poured on it very cautiously, which, by its weight, forces out the solution still remaining in it; and this must be repeated till thirty-six ounces have passed through, and which is known by having the bottle previously marked at the requisite height. Having procured the proper quantity, it must be well mixed, that it may be of uniform strength.

In preparing solution of potassa, it is of consequence to know if the whole of the carbonic acid has been removed, and which is easily done by the addition of lime water, for if free from it, it will remain transparent, but if it still contains it, will become turbid from the deposition of carbonate of lime.

The mode of obtaining potassa from the solution has been described, *(p. 374.)*

As the common carbonate of potassa contains a great deal of soluble foreign ingredients, and as they are not removed by lime, they pass through the filter along with the potassa, and hence the solution itself is not pure, and the process by which pure potassa is obtained from

it is very troublesome and expensive. By employing bicarbonate, an alkaline fluid is procured, from which the alkali is got free from foreign matter, merely by evaporation.

As lime has a stronger attraction than ammonia for muriatic acid, it decomposes muriate of ammonia, uniting with its acid, and disengaging its alkali; and hence the method of preparing it either gaseous or in solution. To obtain gaseous ammonia, we must have recourse to a mecurial trough, or it may be collected sufficiently pure by the displacement of the air; but as it is lighter than it, we must use the precaution of inverting the receivers. For this purpose equal parts of slaked lime and muriate of ammonia in powder are placed into a retort, *(2d cut, p. 315.)* On the application of heat, the ammonia is given off, bringing along with it the water of the slaked lime, which is condensed in the bulb, while the former flowing on gradually, pushes down the air, and fills the receiver.

The preparation of the aqua ammoniæ is a pharmaceutical process. The proportions given by the Edinburgh College are,

Muriate of ammonia, one pound;
Quick lime, one pound and a half;
Distilled water, one pound;
Water, nine ounces.

After slaking the lime with the water, and having allowed it to become cold, it is put with the salt into a retort, to which a bent tube is fixed, and made to pass through a tight cork into a receiver, containing the distilled water, and kept cold in the usual way, *(1st cut, p. 315.)* Heat is then applied through the medium of a furnace and sand bath, (or if small quantities are used, by a lamp,) till the gas ceases to come off. The ammoniacal solution thus procured is of sp. gr. about 936.

In the decomposition of muriate of ammonia, muriate of lime, mixed however with pure lime, remains in the retort, but from which it is freed by solution in warm

water and filtration, and again filtering after exposure to air for some time, to remove the dissolved earth by absorption of carbonic acid. For most purposes, however, as when the muriate is to be used for generating cold, there is no necessity for the second filtration; the solution may at once be evaporated to dryness.

Lime is employed in large quantity in agriculture, either fresh, burned, or in the state of carbonate. When pure lime is mixed with vegetable matter, they act on each other, and form a sort of compost, part of which is soluble, and thus it renders nutritious what was formerly inert. It is in this way that it is supposed to act, (Davy's Agricultural Chemistry,) in fertilizing soil that abounds in vegetable matter, as the roots and stems of the crop previously cut; of course, its action must be the same, when used for cultivating waste ground. Carbonate of lime, or limestone, has no action of this kind; on the contrary, it prevents the too rapid decomposition of vegetable matter, so that, when soil abounds with this, already in the same state as that produced by the action of quick-lime, mild lime is used; and for this purpose marl is commonly employed.

Lime is employed as mortar in two different ways, either for dry building, or for building under water. In preparing mortar for the former purpose, the lime is first slaked, and after being sifted, to free it from impurities, it is mixed with sand, and made into a paste with water, which must be well beat, that the materials may be intimately incorporated.

It is a subject of common regret, that mortar, as now made, is far inferior to that used by the ancients; from which it is supposed, that they must have had some mode of preparing it with which we are unacquainted. The imperfection in this article is, however, to be ascribed more to carelessness, than to ignorance of a good method of making it; for when proper attention is paid to the process, it can be procured equal to that in old buildings.

The first thing to be attended to, is the choice of the lime, which, if possible, ought to be of a brownish colour, as it forms a harder cement than that nearly colourless. It must of course be well burned, so as to be easily slaked, after which it must be passed through sieves, that the stony impurities and unslaked part may be removed. It is also of material consequence to be particular with respect to the sand; the sharper and coarser it is, so much the better, as it requires less lime, and forms a harder cement than the finer kind. Pit-sand is preferable to that from the sea-shore, as the latter contains impurities, which prevent the hardening of the mortar. The same is, however, the case with the former, if it contain clay, which it sometimes does; so that, when pit-sand is used, it must be chosen as pure as possible. Particular attention must likewise be paid to the mixing of the materials, for the more intimately they are blended, the more completely does the mortar become hard. The mixture ought therefore to be well beaten with a wooden mallet, till it does not adhere to it. It is also the better of being kept for some time, provided it is excluded from the air, to prevent it from absorbing carbonic acid; for which reason it must be covered with sand, and before it is used, it must again be beat up with the mallet.

Another kind of mortar is employed for building under water, as that already mentioned does not harden in it. The substance used by the Romans for this purpose, is that called *puzzolana*, a light porous body, of a reddish colour, said to be lava from Vesuvius. In preparing mortar with this, it is reduced to coarse powder, and mixed with lime, either with or without sand, in which state it very soon hardens, even under water. Of course, the same precautions must be followed as in the preparation of common mortar, with respect to the mixing of the materials. The best proportions seem to be about equal parts, by measure, of slaked lime and puzzolana. In some cases, where the building is not much exposed, the quantity of the latter may be diminished, and sand substituted. The substance called *tarras*, made use of

by the Dutch, is merely a sort of whin-stone reduced to powder, and employed in the same way as puzzolana, but the proportions of the materials are different; it is commonly mixed with twice its bulk of lime, to which occasionally three of coarse sand are added. Other substances are sometimes used in this country for a similar purpose, as common whin-stone, and iron-stone, which, when properly mixed with lime, afford a mortar that hardens under water.

Connected with the use of lime in making mortar, is its employment in the preparation of cements. A cement is a substance used for joining bodies, or for covering them, to keep them from being acted on by fire or some other agent; of course its nature differs according to the use to which it is applied, but in many, lime forms a principal ingredient. The most common cement containing it, is that made of white of eggs. It is prepared by beating well together equal quantities of white of eggs and water, and then mixing with it as much slaked lime as will bring it to the consistence of thin paste, in which state it is applied to the places to be joined. Or it may be spread on paper or linen, with which the juncture must be covered. Another way of using this cement, is to spread the white of eggs on paper, and sprinkle it with the powder of lime. Instead of white of eggs, a solution of isinglass or glue in warm water is sometimes employed.

Though the cements mentioned are not apt to be affected by water, they do not answer for preventing the escape of noxious vapours, others must therefore be used. The most common of these, is drying oil made into a thick paste with lime, or with white lead, which answers equally well; indeed, what is now commonly used, is merely white lead paint, which, when applied to junctures, becomes, after standing some time, quite hard, and is not acted on by water; hence its frequent use in cementing glass. A cement of a similar nature is made with cheese and lime. It is prepared by boiling in water the poorest skimmed milk cheese, till it becomes soft, after which the fluid is poured off, and it is then well

kneaded, first in cold, and then in warm water, and mixed with quick-lime, in which state it is applied to the junctures. It answers well for joining pieces of earthenware, glass, or marble.

Lime, from its powerful attraction for water, is employed for preserving substances that are liable to be injured by moisture, as deliquescent salts, or iron instruments. For this purpose, a quantity of it is placed at the bottom of a tin cannister, and over it the substances to be kept dry. When the whole of it seems to be slaked, and which is known by its having fallen into powder, it must be renewed.

Owing to the strong attraction of lime for carbonic acid, it is used for freeing gases of this elastic fluid, as in the preparation of carburetted hydrogen, (p. 231.) and in the manufacture of coal gas, *(See Coal.)* From the same property, it is used also for ascertaining the quantity of carbonic acid existing in any gas, and which is done by a eudiometer, as in finding the proportion of oxigen by means of the solution of hydro-sulphite of potass, filling the bottle with milk of lime, and using the same precautions as then mentioned, (p. 427.)

BARIUM AND BARYTA.

Baryta, like the other earths, was, till the discoveries of Davy, considered a simple body. In subjecting it to the action of his powerful battery, he observed slight traces of decomposition, but he succeeded more effectually in decomposing it by a process similar to that by which lime was decomposed,—by negatively electrifying it with oxid of mercury. The result was a metallic-looking substance, of a dark grey colour, and heavier than sulphuric acid. When exposed to the air, it acquired a crust on its surface. When gently heated, it burned with a deep red flame. When thrown into water, it excited a violent effervescence, instantly falling to the bottom, and baryta was formed. To this substance the name of *Barium* has

been given. Its properties have not been farther examined.

Baryta.

Baryta was discovered by Scheele and Gahn in 1774. From the great weight of its compounds it was first called *terra ponderosa*, which was afterwards changed to *baryta*, derived from the Greek word βαρυς, *heavy*.

It is a greyish, porous substance, similar in its appearance to recently burned lime, but in its taste it is much more acrid. It corrodes animal and vegetable matter, and acts as a powerful poison.

From the experiments of Davy and Berzelius, it appears to be composed of

barium, -	89.75
oxigen, -	10.25

and from the experiments of Thomson, (First Princ.) it contains an atom of each of its ingredients. If so,

as 10.25 : 89.75 : : 10 : 87.5,

so that the atomic weight of barium is,	87.5
of baryta,	97.5

When baryta is exposed to air, it quickly attracts moisture, and falls into powder in the same way as lime, and it combines also with carbonic acid. Hence the necessity of keeping it in well-stopped phials.

The phenomena presented by the addition of water, are similar to those with lime, the earth being slaked, but it gives out much more heat.

Baryta is very soluble in water, which when cold dissolves 1-25th, and when warm nearly half its weight of it. The solution is transparent and colourless, and, like lime, changes vegetable blues to green. When exposed to air, it absorbs carbonic acid, and becomes muddy, from the deposition of carbonate. When a concentrated warm solution is allowed to cool gradually, crystals are formed, which are flat hexagonal prisms. These are soluble in about 17 of cold water. When exposed to air they effloresce, and when heated they undergo watery fu-

sion; and hence they must contain a large quantity of water. It is supposed that baryta unites with three proportions of it, and forms different compounds. That with the largest is the crystallized earth; the second is obtained by heating the crystals to redness, by which they give off only half of their water; and the third is procured by the exposure of the pure earth itself to heat, for though strongly heated it still retains water.

Baryta requires a very intense heat for its fusion; that of the oxi-hydrogen blow-pipe being necessary.

When heated in oxigen gas, or when the gas is passed over it in an incandescent tube, it imbibes it with avidity, and forms a greyish compound called *peroxid of barium*, which, when thrown into water, gives off to it its excess of oxigen, and is reduced to the state of baryta. It was by this that Thenard prepared oxigenated water, or peroxid of hydrogen, (*see p.* 203.) For this purpose, he took 4½ pints of water, and added as much muriatic acid as would neutralize 232 gr. of baryta; 185 of the peroxid were then thrown, in successive portions, into the acidulous fluid, kept cold by being surrounded by ice, by which muriate of baryta was formed, and the excess of oxigen communicated to the water. Sulphuric acid was next added, to precipitate the baryta in the state of sulphate, after which it was boiled with sulphate of silver, to throw down the muriatic acid. The oxigenated water, still containing sulphuric acid, derived from the sulphate of silver, after being mixed with baryta, by which this was precipitated, was placed under the receiver of an air-pump, along with sulphuric acid, as in Leslie's experiment for generating cold, and concentrated by evaporation. It was thus procured, containing 475 times its volume of oxigen. (London Journal of Science, 1819.)

The action between baryta and phosphorus, sulphur, or chlorine, is the same as with lime, the water being decomposed, and giving rise to the formation of compounds containing its ingredients. When also chlorine gas is passed over baryta, at a red heat, oxigen is disengaged;

for each volume of the former imbibed, half a volume of the latter is liberated, and chlorid of barium is the product.

Salts of Baryta.

Baryta unites readily with the acids, and forms salts easily distinguished from those of lime.

Nitrate of Baryta.

Nitrate of baryta may be procured by the addition of the acid to the pure earth, or, which is more economical, to the carbonate. It may also be prepared by adding it to the product of the decomposition of the sulphate, by charcoal, as will be afterwards described. By the evaporation of the solution, crystals of an octahedral form are procured, the taste of which is acid.

It is not altered by exposure to air. When subjected to a strong heat, it is decomposed, the acid being expelled, and the earth left pure, and hence the method by which baryta is obtained. In conducting the process, the heat must not be very intense, because the earth, at a high temperature, is apt to attack the materials of the crucible. The product, when cool, must be removed, and kept in well-stoppered bottles.

Nitrate of baryta is soluble in 12 of cold, and in about 3 of boiling water.

It is composed of

1 atom of acid,	67.5	or	59
1 atom of baryta,	97.5		41
its atom being	165.		100

Besides being used for yielding the pure earth, it is employed in the purification of nitric acid. If, after diluting the acid with about 2 parts of distilled water, a precipitate appears on the addition of the nitrate, it contains sulphuric acid, the precipitate being sulphate of baryta. The nitrate must therefore be added as long as there is any precipitation, after which the powder may

be allowed to fall, and the supernatant fluid poured off; or, which is better, it may be distilled. Of course, the original nitric acid, and that set free from the nitrate, come over together.

Carbonate of Baryta.

Carbonate of baryta may be formed by adding carbonic acid water to solution of baryta, or by mixing an alkaline carbonate with the nitrate. It is not, however, prepared in this way for use, being a native production. It is found crystallized and amorphous, the crystals varying much in their form. They are sometimes double, four, or six-sided pyramids, and occasionally hexagonal prisms. The sp. gr. is 4300.

Carbonate of baryta is tasteless, and very sparingly soluble, requiring upwards of 4000 of water to dissolve it. It is poisonous, for which reason it is frequently used for poisoning rats.

The results of the action of heat differ according as we employ the native or artificial carbonate. From the latter the acid is easily expelled, whereas from the former it is not driven off but by the most intense heat, and which is supposed to be owing to the presence of water, which acts by its affinity for the earth. Hence, if steam be passed over the native carbonate, at a red heat, it is easily decomposed. According to the experiments of Klaproth and Rose, it is composed of

1 atom acid,	27.5	or	22
1 atom baryta,	97.5		78
its atom being	125.		100

All the acids decompose it, disengaging its acid, and uniting with its base; and hence a method of preparing the different barytic compounds, though this mode is not much followed, because the carbonate is by no means an abundant production of nature.

Sulphate of Baryta.

Between sulphuric acid and baryta there exists a very strong attraction, so much so that it will seize it from any of its compounds. When the acid is thrown on the earth, they unite, and heat is evolved, sufficient to make the mixture red-hot. Sulphate of baryta is not, however, prepared in this way, being an abundant native production, occurring both in mass and crystallized; of which there are different kinds, as the straight lamellar, the granular, the columnar, the compact, and Bolognian heavy spar, the first the most abundant.

Sulphate of baryta, whether artificial or native, is tasteless and insoluble. Its sp. gr. is 4400. When the latter is heated, it decrepitates, after which it is easily reduced to powder, and if the heat is very intense, it is fused.

Very different statements have been given of the composition of the sulphate, but it has of late been analyzed with great care, and the proportions of its ingredients ascertained with accuracy. The experiments of Kirwan, Aiken, Fourcroy, Berzelius, and Berthollet, very nearly agree in stating them at,

acid 34, baryta 66,

and which is the composition according to the atomic doctrine;

for as 34 : 66 : : 50 : 97;

so that we may consider it composed of

1 atom of acid	50	or	33.89
1 atom of baryta	97.5		66.11
and its atom	147.5		100

Sulphate of baryta, like other sulphates, is decomposed by charcoal at a red heat, by which the oxigen of both of its ingredients is removed, and *sulphuret of barium* is left.

The alkaline carbonates decompose it, and carbonate of baryta is formed; and hence a method of preparing the carbonate when it cannot be otherwise procured, and

for which purpose one part of finely powdered sulphate is exposed in a crucible to a red heat, with three of carbonate of potass. Though carbonate can thus be obtained, the whole of the sulphate is not destroyed, even though the heat is continued; and though the soluble matter can be washed away, yet the carbonate cannot be separated from the undecomposed sulphate. The process is, however, practised, when the carbonate is required for converting it to pure baryta, because the earth being soluble, it can be washed off from the insoluble matter.

Sulphate of baryta is also partially decomposed by muriate of soda and muriate of lime, and hence a method of preparing the muriate. *(See Muriate.)*

Chlorate of Baryta.

Chlorate of baryta is prepared in the same way as the alkaline chlorates, by passing a stream of chlorine gas through solution of baryta; and of course the action is the same, the water giving its ingredients to the chlorine, to form muriatic and chloric acid, both of which combine with the earth. As they are both soluble, the solution is boiled with phosphate of silver, by which muriate of silver and phosphate of baryta are precipitated; so that by filtration, chlorate of baryta is procured.

This salt is valuable only as affording chloric acid by its decomposition, as pointed out by Thenard, (An. de Chim. xci.) For this purpose, sulphuric acid is added to the solution as long as it causes precipitation of sulphate of baryta. The fluid, when filtered, supposing just the proper proportion of sulphuric acid to have been added, is pure chloric acid.

Muriate of Baryta.

Muriate of baryta is another important compound. It was first examined by Scheele, and afterwards by Crawford and Kirwan. It crystallizes in tables, occasionally in two eight-sided pyramids, joined by their

bases. It has a pungent taste, and when swallowed in large quantity, is poisonous. It is soluble in about 5 of cold, and in less of boiling water. It is not altered by exposure to air. When heated, the water of crystallization is expelled, and the oxigen of the earth, and hydrogen of the acid, being also disengaged in the form of water, a *chlorid of barium* remains.

Muriate of baryta, according to the most accurate analysis, consists of

acid	32.17	earth	67.83

that is,

1 atom acid	46.25
1 atom earth	97.5
	143.75

and as when heated it is converted into chlorid by the loss of oxigen and hydrogen, it is evident that the chlorid thus formed must also contain an atom of each of its component parts; and if so, its composition will be

chlorine	45	or	34
barium	87.5		66
	132.5		100

Muriate of baryta is decomposed by sulphuric acid, and the alkaline sulphates, by which sulphate is precipitated. It is also decomposed by the carbonates, which throw down a carbonate. Owing to the ease with which it gives off its base to sulphuric acid, it is employed in the purification of muriatic, for which purpose its solution is mixed with it as long as there is any precipitation; and if the acid is required concentrated, it is subjected to distillation.

Muriate of baryta may be prepared by the addition of muriatic acid to the carbonate; but as this is not an abundant production, we are frequently obliged to have recourse to the decomposition of the sulphate. The process is pharmaceutical.

The Edinburgh College orders two pounds sulphate,

after being heated and reduced to fine powder, to be exposed, with four ounces of powdered charcoal, to a red heat for six hours. The residue is then dissolved in water, excluded from air; and after the whole of the soluble matter is extracted by repeated washings, muriatic acid is added to the solution, and, by filtration and evaporation, crystals of muriate are obtained.

Very different statements have been given of the chemical changes accompanying the formation of the muriate. It was at one time supposed that there was in the first part of the process the decomposition only of the sulphuric acid, its oxigen being removed by the charcoal, and that *sulphuret of baryta* was produced. It has been proved, however, by the experiments of Berthier, (An. de Ch. et de Ph. xxii.) that in all those instances in which a sulphate is decomposed by charcoal, both the acid and base are deprived of oxigen, and that the sulphur and metallic matter are left in combination. Keeping this in view, along with the general law already so repeatedly mentioned with respect to the action of water on sulphurets, we can easily account for the changes produced. When the sulphate, after being roasted, is heated with charcoal, the oxigen of the acid and base come off in the state of carbonic acid or oxid, while the sulphur and barium form a sulphuret, which, when thrown into water, becomes hydro-sulphate of baryta, and on the addition of muriatic acid to the solution, sulphuretted hydrogen is disengaged, and muriate is produced.

These decompositions may be explained, according to the atomic doctrine:

$$1 \text{ atom sulph. bar.} = \begin{cases} \text{acid} \quad 1 = \text{sulphur} \quad 1 \\ \text{baryta} \quad 1 = \text{barium} \quad 1 \end{cases}$$

so that, when deprived of its oxigen, it becomes

$$1 \text{ atom sulphuret barium} = \begin{cases} \text{sulphur} \quad 1 \\ \text{barium} \quad 1 \end{cases}$$

This, when thrown into

$$1 \text{ atom water} = \begin{cases} \text{oxigen} \quad 1 \\ \text{hydrogen} \quad 1 \end{cases} \text{ becomes}$$

$$1\text{ atom hydro-sulphate} = \begin{cases} \text{sulph. hyd. } 1 = \begin{cases} \text{sulphur } 1 \\ \text{hydrogen } 1 \end{cases} \\ \text{baryta } 1 = \begin{cases} \text{oxigen } 1 \\ \text{barium } 1 \end{cases} \end{cases}$$

The hydro-sulphate, when decomposed by muriatic acid, loses its sulphuretted hydrogen, and becomes

$$1\text{ atom muriate} = \begin{cases} \text{acid } 1 \\ \text{baryta } 1 \end{cases}$$

Though these are the changes effected when the substances are pure, yet it is difficult to get the sulphate completely converted to sulphuret. Owing to the moisture always existing in the charcoal, part of it is decomposed, and gives rise to the formation of super-sulphuretted hydrogen, which unites with some of the baryta, so that when the product is thrown into water, there is both hydro-sulphate, and sulphuretted hydro-sulphate; and hence it is, that on the addition of muriatic acid, there is always, in the common way of preparing it, a deposition of sulphur, from the disengagement and decomposition of the super-sulphuretted hydrogen. When, however, the sulphate and the charcoal are separately exposed for some time to a red heat, and are, after being mixed, immediately heated, a substance is procured, the solution of which, though it gives off sulphuretted hydrogen, does not afford any precipitated sulphur; so that it must be a pure hydro-sulphate, and consequently the product of the decomposition of the sulphate, must be a pure sulphuret of barium.

Muriate of baryta may also be obtained, by exposing equal parts of the powder of the sulphate, and of muriate of lime or of soda, to a red heat in a crucible, by which there is a double decomposition. The product by solution and evaporation, affords crystals of the muriate.

From the strong attraction of baryta for sulphuric acid, it is employed as a test of it, but instead of the pure earth, one of its salts is preferred, as the nitrate or muriate; of course they are also used for ascertaining the quantity of acid existing in any solution. *(See Mineral Waters.)*

STRONTIUM AND STRONTIA.

Strontia was discovered by Dr Hope, in a mineral found in Strontian in Argyllshire, and which had been previously examined by Pelletier, who concluded that it contained baryta. In 1792, Dr Hope (Ed. Phil. Tr.) proved that the earth in it was different from the others then known, and gave it the name of *strontites*, which was afterwards changed to *strontiana*, and *strontia;* the last, the one generally adopted. Its existence was much about the same time proved by Klaproth and Pelletier.

It is a porous greyish-coloured substance, similar in its appearance to baryta, having an acid taste, but not poisonous. Its sp. gr. is 1600.

Davy succeeded, by a process the same as that to which baryta was subjected, in decomposing strontia, and obtained a metallic-looking matter, to which he gave the name of *strontium*. When exposed to air, or thrown into water, oxigen was absorbed, and strontia was generated.

According to the experiments of Thomson and others, 100 strontium combine with 18.18 of oxigen, to form strontia; and as this is supposed to be a compound of an atom of each of its ingredients, the atomic weight of strontium will be 55, and of strontia 65, for as

$$18.18 : 100 :: 10 : 55, \text{ and } 55 + 10 = 65.$$

When strontia is exposed to air, and when water is thrown on it, it presents the same phenomena as baryta, being slaked and giving out heat. It is not, however, so soluble, requiring 162 of cold water to dissolve it. The solution is transparent and colourless, and, like that of baryta and lime, changes blues to green, and absorbs carbonic acid on exposure to air. It is much more soluble in warm water; the solution, on cooling, depositing crystals, which are thin quadrangular plates grouped together, and containing about 68 per cent. of water. When heated, they undergo watery fusion. They are soluble in $51\frac{1}{2}$ of water at 60, and in about 2 at a boiling heat.

On exposure to air they effloresce, and at the same time absorb carbonic acid.

If the substance obtained by making the crystals undergo watery fusion, be exposed to a red heat, it becomes fluid, but pure strontia requires the heat of the oxi-hydrogen blow-pipe for its fusion.

The action between strontia and the simple acidifiable bodies, is the same as with lime and baryta.

Salts of Strontia.

Strontia unites with the acids, and forms compounds, in which the difference between it and baryta is more easily observed, than in the pure earths themselves.

Nitrate of Strontia.

Nitrate of strontia is formed by the addition of diluted nitric acid to the carbonate, and evaporating the solution, by which crystals are obtained in the form of dodecahedrons, composed of two six-sided pyramids, joined by their bases. It has a cooling pungent taste, soluble in its own weight of cold, and in half its weight of boiling water.

The composition given by Stromeyer, is

acid,	50.64	or 1 atom	67.5
strontia,	49.38	1 atom	65.
the atom of the nitrate being			132.5

Nitrate of strontia occurs also in union with water, forming a salt, crystallizing in acute rhombs, and efflorescent. It consists of 1 atom of acid, 1 of base, and 4 of water.

When nitrate of strontia is exposed to heat in a crucible, it is fused, and if the temperature be increased, it is decomposed, the whole of the acid being expelled, and the earth left pure; and hence the method by which it is generally obtained, merely by heating the nitrate in an iron or platinum crucible, excluded from air, till acid

fumes cease to come off, and putting the product, when removed from the fire, into a well-stoppered phial.

Nitrate of strontia deflagrates when heated with inflammable matter, and during the deflagration, the flame assumes a beautiful red tinge, a character peculiar to the salts of this earth; and hence an easy method of distinguishing them from those of baryta. On putting a crystal of nitrate of strontia on the wick of a candle, the flame instantly becomes red; whereas, when a barytic salt is used, there is very little change. For the success of this, however, water must be present. If, for instance, when the red tinge of the flame has ceased, the wick be touched with water, it instantly re-appears, and this may be repeated several times. Hence also the use of nitrate of strontia in making red signal lights, which are prepared by mixing 34 parts of nitrate of strontia, 4 of sulphur, 1 of charcoal, and 2 of sulphuret of antimony, and to which there is sometimes added 2 of chlorate of potass, the last of which must of course be reduced to powder *alone*, and then mixed cautiously with the others.

Carbonate of Strontia.

Carbonate of strontia may be formed by the addition of carbonic acid water to solution of strontia, or by mixing alkaline carbonate with the nitrate, by which a white tasteless insoluble powder is precipitated. It is not, however, prepared in this way, being a native production. It occurs in Strontian in Argyleshire, where, as has been already mentioned, the mineral was found in which it was discovered by Dr Hope. It is generally massive, either fibrous or columnar, but it is occasionally crystallized. It is usually of a greenish colour. When exposed to a strong heat, its acid is driven off, and hence another method of obtaining the pure earth; but for this purpose the artificial carbonate ought to be used, as from it the carbonic acid is more easily expelled than from the other.

It is composed of

acid,	30 or 1 atom,		27.5
strontia,	70	1 atom,	65.
			92.5

the atom of the carbonate being

All the acids decompose it, uniting with its base, and hence the method by which the different strontitic salts are formed.

Sulphate of Strontia.

Sulphate of strontia may be formed by the addition of sulphuric acid, or an alkaline sulphate, to the nitrate, by which a white powder is deposited, differing from sulphate of baryta in being soluble, though sparingly so, requiring 3840 of water, at a boiling heat, to dissolve it.

According to Stromeyer, its composition is, acid 43, strontia 57, or an atom of each, which would make it 43.47 to 56.53.

Like other sulphates, it is decomposed by heat and charcoal, yielding a sulphuret of strontium, which, when thrown into water, becomes a hydro-sulphate; and, as this is decomposed by acids, hence another mode of forming the soluble compounds of strontia; for, after decomposing the sulphate, and dissolving the product, we have merely to add to the solution the acid with which we wish the earth to combine, then filter, and evaporate.

Sulphate of strontia is also a native production, occurring both massive and crystallized. It is found near Bristol, and in some parts of Sicily.

Muriate of Strontia.

Muriate of strontia is procured by dissolving the carbonate in muriatic acid, but which must be diluted, because the strong acid acts slowly on it; or it may be obtained by the addition of the acid to the solution of the decomposed sulphate. By evaporation slender prismatic crystals are deposited, having a sharp peculiar taste, deliquescent, and very soluble, requiring less than their own weight of water, at a natural temperature, for solu-

tion. When subjected to heat they lose upwards of 40 per cent. of water, and become chlorid.

Very different statements have been given of the composition of this salt. It is, according to Thomson, composed of

1 atom acid,	46.25	or 22.98
1 atom strontia,	65.	32.98
9 atoms water,	101.25	41.04

In exposing it to heat, in addition to the water of crystallization, that formed by the union of the hydrogen of the acid and oxigen of the base is also given off.

The muriate, like the nitrate, tinges the flame of burning bodies red. It is decomposed by the alkaline carbonates and sulphates which precipitate carbonate and sulphate of the earth.

Strontia has no action with the alkalies. It decomposes the alkaline carbonates and sulphates, depriving them of their acids. It is not put to any use. The only compound employed is the nitrate, which, it has been already said, is used in the manufacture of red signal lights.

MAGNESIUM AND MAGNESIA.

About the beginning of the 18th century, a white powder known by the name of *magnesia alba*, was in common use in the cure of some diseases, and was generally believed to be lime, till Hoffman, in 1722, proved that it was altogether different from it, more particularly in the properties of its compounds. It was not, however, till the discoveries of Dr Black, in 1775, that we became acquainted with its true nature. He first shewed that it contained an earth different from those then known, and to which the name of *magnesia* has been given. This term is still, however, applied by some to the other substance; thus, the magnesia of commerce is that from which the pure earth is obtained, while the latter is generally sold by the name of *calcined magnesia*, or *magnesia usta*.

Davy succeeded in decomposing magnesia by a process similar to that by which the other earths were decomposed, but it was very tedious, and he did not procure the metallic matter pure from the amalgam, owing to its acting on the glass of the tube. In one experiment in which the distillation was stopped before the whole of the mercury was expelled, a white metallic substance was obtained, which, when exposed to air or thrown into water, absorbed oxigen, and generated magnesia. To this the name of *magnesium* has been given,—the only known compound of which with oxigen is magnesia; but the proportions have not been established by experiment. The atomic weight of magnesia is, according to Dr Thomson, 25, and as it is supposed to contain an atom of each of its ingredients, that of magnesium is 15, (25 — 10 = 15;) if so, its composition will be,

magnesium 60, oxigen 40.

Magnesia is a white light powder without taste or smell. Its sp. gr. is 2300. It does not suffer any change by exposure to the heat of a powerful furnace, but it can be fused by the oxi-hydrogen blow-pipe.

When exposed to air, it undergoes very little, if any change. Like other powders, it absorbs moisture, but it does not seem to attract carbonic acid, at least if it does, it must unite with it very slowly, for Butini found, that in the course of two years it increased only 1-144th in its weight; in this respect, it differs from the earths already described.

It is very sparingly soluble, and in its solubility it resembles lime, being taken up in greater quantity by cold than by warm water. It requires 5142 of the former, and no less than 36,000 of the latter to dissolve it; hence a cold solution, the moment that it begins to boil, becomes turbid. The solution is transparent and colourless, and, like those of the preceding earths, changes blues to green. (Ed. Phil. Journ.)

Though there is no particular action on the addition of water to magnesia, yet there is an affinity between them. It has been found native in the state of *hydrate*, and

when thrown down from the solution of any of its salts, it also retains water. The composition of the precipitated magnesia varies, and it does not seem, from any of the statements, that the ingredients are in atomic proportions. The native compound is, however, a *proto-hydrate.* According to analysis, I have found it composed of earth 69.75, water 30.25, or an atom of each. (Ed. Ph. Journ.)

Magnesia differs from the other earths already noticed, in not acting with sulphur and phosphorus. When chlorine is passed over it, oxigen gas is disengaged, and chlorid of magnesium remains, each volume of the former consumed setting free half a volume of the latter.

Salts of Magnesia.

Magnesia unites readily with the acids, and forms compounds, which in general are soluble, and differ much in their qualities from those of the preceding earths, and it possesses also the property of uniting along with other bases, and forming triple salts.

Nitrate of Magnesia.

Nitrate of magnesia may be formed by saturating the acid by the addition of the earth or its carbonate, and evaporating the solution, by which prismatic crystals may be procured. These, on the application of heat, first undergo watery fusion, and on the continuance of it, give off the acid, and leave the earth pure.

According to Thomson, they are composed of

1 atom acid,	67.5	or 42.18
1 atom magnesia,	25	15.64
6 atoms water,	67.5	42.18
	160	100

Nitrate of magnesia is decomposed by the alkalies and their carbonates. The action with ammonia is important, because by it a triple nitrate of magnesia and ammonia is formed, which is deposited in the state of a white

powder, and which, like the nitrate, is decomposed by heat, the ammonia and acid being expelled.

Carbonate of Magnesia.

Carbonate of magnesia, but not pure, may be obtained by the addition of an alkaline carbonate to a magnesian salt, by which a white light powder resembling the pure earth is precipitated. It is tasteless and inodorous. Of sp. gr. 2300. It is not altered by exposure to air. Subjected to a moderate heat, it becomes phosphorescent, and when the temperature is high, is decomposed, the acid being expelled, and the pure earth left, and hence the method recommended in the pharmacopœias for preparing it. All that is necessary is to expose it to a red heat in a crucible. It is from this method of procuring it, that pure magnesia is commonly called *magnesia usta*, or *calcined magnesia*.

Carbonate of magnesia is soluble, though very sparingly so, and in its solubility it resembles the pure earth, being more soluble in cold than in warm water. The solution is transparent and colourless, and changes vegetable blues to green.

Different opinions are entertained with respect to the composition of the compound formed by the decomposition of the magnesian salt by the alkaline carbonate. Berzelius considers it composed of carbonate and quadrihydrate of magnesia, in the proportion of 3 of the former to 1 of the latter. In other specimens, the composition was different, which seemed to be occasioned by the mode of preparing it.

Pure carbonate of magnesia occurs native and anhydrous. It exists in great abundance in Hindostan, where it forms immense mountains. According to the analysis of Thomson and Stromeyer, it is composed of

1 atom acid,	27.5	or 52.38
1 atom base,	25	47.62

Pure carbonate of magnesia may also be formed artificially, by passing a stream of gas through water, holding magnesia suspended in it, and filtering and crystalliz-

ing it. It is more soluble than the common carbonate, requiring only about 48 of cold water to dissolve it. When exposed to air it effloresces, and becomes anhydrous. According to Berzelius, it is composed of

1 atom acid,	27.5	or 32
1 atom earth,	25	28.6
3 atoms water,	33.75	39.4

All the acids decompose carbonate of magnesia, uniting with its base, and liberating its acid. When carbonic acid gas is passed through water, holding it in suspension, a transparent solution is formed, commonly sold under the name of *aerated magnesia water*, and which is used for the same purposes as soda water.

Carbonate of magnesia is used in medicine as a corrector of acidity, and in calculous complaints, in the latter of which it is generally taken in the form of the magnesia water.

Phosphate of Magnesia.

Phosphate of magnesia may be formed by the addition of an alkaline phosphate to a soluble magnesian salt, by which a white powder is precipitated, provided concentrated solutions are used; but when they are diluted, the phosphate is gradually deposited in slender six-sided prismatic crystals. They are sparingly soluble. They effloresce on exposure to air, and on the application of heat, lose their water of crystallization.

They consist, according to Thomson, of

1 atom acid,	35
1 atom base,	25
7 atoms water,	78.75

If to the solution of phosphate of magnesia, ammonia be added, a white precipitate of *phosphate of magnesia and ammonia* appears. It may also be formed by the addition of ammonia, or its carbonate, to a mixture of diluted solutions of phosphate of soda, and a magnesian salt. It is insoluble in water. When heated, it emits an ammoniacal odour, and if the heat be strong, the whole of the alkali is disengaged, and phosphate of magnesia remains.

When heated with charcoal, the acid is decomposed, and phosphorus distils over.

Sulphate of Magnesia.

Sulphate of magnesia is perhaps the most interesting of the magnesian salts. It may be procured by saturating the acid by the earth or its carbonate, but there is no necessity for preparing it in this way, being more easily obtained from other sources to be immediately mentioned. It exists in many mineral waters, as those of Epsom, from which it has been called *Epsom salts*, and it occurs also in sea water, from which it is usually procured. For this purpose, the fluid that remains after the sea salt has been extracted, and which is called *bittern*, is evaporated, during which sulphate of magnesia is deposited. But besides sulphate, bittern contains also muriate of magnesia, and as from it muriatic acid is sometimes procured for particular purposes, by the addition of sulphuric acid, the residue, on evaporation, yields crystals of sulphate. In those countries where minerals containing magnesia abound, the sulphate is obtained from them by exposing them to air and moisture, by which the sulphur they contain is acidified, and combines with the earth, so that by solution, filtration, and evaporation, crystals can be procured.

Sulphate of magnesia crystallizes in quadrangular prisms, terminated by four-sided pyramids. It has a sweetish bitter taste. Provided it is pure, it is not altered by exposure to air, but as usually obtained, it is deliquescent. When heated, it undergoes watery fusion, and by continuance of it, the water is expelled, and the dry salt is left, which bears a most intense heat without becoming fluid. It is soluble in its own weight of cold, and 3-4ths of boiling water.

The composition of sulphate of magnesia has been differently stated by authors. According to the best analysis, it is composed of

acid,	32.72	1 atom,	50
base,	16.26	1 atom,	25
water,	51.22	7 atoms,	78.75
	100		153.75

Sulphate of magnesia is decomposed by the alkalies, and some of the alkaline carbonates; and hence a method of procuring magnesia, or its carbonate; the latter of which is a pharmaceutical process. It consists in mixing the solution of 4 parts of the sulphate with that of 3 of carbonate of potass, having previously filtered them. The mixture is then to be boiled and filtered, by which carbonate of magnesia is procured. The reason for boiling, is to drive off any excess of carbonic acid, which would keep part of the carbonate in solution. If, instead of using carbonate, a solution of bi-carbonate be employed, there is no precipitation, because the soluble super-carbonate of magnesia is formed; but on boiling, the powder of carbonate is deposited.

On the addition of carbonate of ammonia to the sulphate there is no decomposition, because the affinity between the acid and earth is too strong; and hence an easy method of separating this earth from the others with which it may be mixed. For instance, on adding the carbonate, the earths already described are precipitated, and on filtering and adding phosphate of soda, the magnesia will be deposited in the form of phosphate of magnesia and ammonia. *(See Mineral Waters.)*

Muriate of Magnesia.

Muriate of magnesia is a natural production. It exists in sea water, and is that ingredient which imparts to it its bitter taste, and impairs its antiseptic qualities. When its solution is evaporated, acicular crystals are obtained, soluble in about half their weight of water. It differs from other muriates in not becoming a pure chlorid when heated, for part of the acid is expelled. According to Henry and Marcet, it constitutes about 1-8th part of the saline mass obtained by the evaporation of sea

water. The mode of removing it from the muriate of soda has been already described in p. 435.

Magnesia is not put to any use, except in medicine, being employed for the same purpose as the carbonate. It abounds in the mineral kingdom. Magnesian fossils are in general soft, have an unctuous feel, and are almost always of a greenish colour. Besides magnesia, they contain silica, which is in general in greatest quantity; but it is the magnesia that gives them their particular properties. Magnesia occurs also in combination with carbonate of lime, in what is called *magnesian limestone*, which is often mistaken for common limestone; and as the magnesia is supposed to be detrimental in agriculture, it is of consequence to be able to distinguish them. *(See Appendix.)*

LITHIUM AND LITHIA.

Lithia was discovered by Arfvredson in the mineral called *Petalite*, and it has since been found also by the same chemist, in the minerals termed *Spodumene* and *Lepidolite*. It was first mistaken for soda; but an examination of its properties soon proved it to be a distinct substance, different from any other then known. (An. de Ch. et Phys. x.) The name of *lithia* has been given to it, derived from λιθειος, *lapideus*, to distinguish it from the fixed alkalies, which are usually derived from vegetable sources. Though it is generally classed along with the alkalies, it seems more properly to belong to the alkaline earths; for though itself resembling alkalies in its properties, yet its salts are not all soluble in water, which is the case with those of potassa, soda, and ammonia. For this reason I have brought it in with the soluble earths.

Different methods have been recommended for procuring lithia, the simplest of which are those of Arfvredson and Berzelius. That of the former consists in fusing petalite with carbonate of potassa, dissolving in muriatic acid, evaporating to dryness, and treating the residue

with alcohol, by which muriate of lithia is dissolved. The muriate is then digested with carbonate of silver, by which muriate of silver is deposited, and carbonate of lithia left in solution, from which the acid can be removed by lime, and by filtration and evaporation excluded from air; pure lithia is left. Berzelius prepares lithia by mixing the mineral with fluor spar and oil of vitriol, and heating the mixture till the whole of the fluo-silicic acid is driven off. The residue is then dissolved, by which sulphate of lithia is obtained, and from which the acid can be removed by baryta, and the earth left pure.

Lithia, like the fixed alkalies and alkaline earths, contains a metallic matter in combination with oxigen. Davy, by subjecting its carbonate to the action of his powerful battery, succeeded in decomposing it, by which minute globules of a metallic matter were formed, but which were almost instantly inflamed. The base thus evolved has been called *Lithium*, the only known compound of which, with oxigen, is lithia; but the proportions have not been determined by experiment. Thomson, (First Pr.) partly from his own experiments, and partly from those of Arfvredson, Berzelius, and Stromeyer, has fixed the atomic weight of lithia at 22.5; and considering it a compound of an atom of each of its ingredients, he considers that of lithium to be 12.5; if so, lithia must be composed of 55 of base to 45 of oxigen.

Lithia has an acrid taste, like that of the fixed alkalies. It is soluble in water, forming a transparent colourless solution, which changes blues to green. It unites with the acids, and forms salts. The sulphate, nitrate, and muriate, are soluble in water, and the last also in alcohol, causing it to burn with a red flame. The carbonate is but sparingly soluble, requiring about 100 times its weight of water for solution. Like the alkaline carbonates, it changes blues to green, and gives off its acid to lime. When fused in a platinum crucible, it acts on it powerfully, like the nitrates of the alkalies.

Phosphate of lithia is insoluble, in this respect resembling the earths.

ALUMINUM AND ALUMINA.

The salt called alum, which has been long in use in the arts, was soon discovered to contain sulphuric acid; but the base with which it was in union, was not known. Newman supposed that it was lime; but Margraaff, in 1754, shewed that it was an earth of a peculiar nature, and the same that exists in clay. He therefore gave it the name of *Argil*, which was afterwards changed to *alumina*, from its being the base of alum. It is sometimes called also *Fuller's Earth*, from clay in which it exists in considerable quantity being employed by fullers.

Alumina, when obtained from alum, differs in its appearance, according to the method followed, particularly with respect to the quantity of water in which the salt has been dissolved. When a concentrated solution has been used, the earth is in the state of a fine white powder; but if it has been much diluted, it forms a transparent gelatinous mass, containing a considerable quantity of water, and for which it seems to have a strong attraction, retaining it with great avidity.

Davy did not succeed in decomposing alumina by galvanism, but he seems by other processes to have effected its decomposition. When it was subjected to the galvanic influence along with potassa, metallic globules were procured, which, when thrown into water, generated potassa and alumina. When heated in the same way along with potassium, similar results were obtained. When also the vapour of potassium was passed over it at a red heat, potassa was formed, and minute globules appeared, which by the action of water generated alumina. From these experiments, there seems no doubt that alumina, like the other earths, is composed of oxigen and a metallic base, to which the name of *aluminum* has been given.

The composition of alumina has not yet been ascertained by direct experiment, nor has its atomic weight been fixed with certainty. Dr Thomson, from reasoning

founded on the composition of minerals, into which it enters as a component part, and from the decomposition of some of its salts, particularly alum, has concluded that the atomic weight of alumina is 22.5, and considering it a compound of an atom of each of its ingredients, that of aluminum will be 12.5.

When alumina is exposed to heat, it contracts, and as the contraction is in proportion to the intensity of the heat, and is permanent, Wedgewood has had recourse to it in measuring high temperatures, (p. 19.)

Alumina does not suffer any change by the heat of a powerful furnace, but it can be fused by the oxi-hydrogen blow-pipe, and it then forms a semi-transparent globule.

Alumina is insoluble; it seems, however, to have a strong attraction for water. As usually obtained, it contains half its weight of it, and if the atomic weight of the pure earth be 22.5, this compound must be a *bi-hydrate*; for 22.5 is the number denoting 2 atoms of water. When this is heated, it becomes a *proto-hydrate*, and on the continuance of the heat, pure alumina remains. Hence probably the cause of the contraction occasioned by a high temperature.

Alumina has no action with the simple acidifiable bodies, in this respect differing from the earths already described.

Alumina unites with the acids; the only compound of any interest is that with sulphuric acid. When the acid is poured on the earth, a solution is formed, which, by evaporation, yields crystals of sulphate, and which were at one time supposed to be the same as alum. It is now known, however, that alum is a triple salt, and is various in its composition, according to the mode of preparation.

Alum.

Different varieties of alum have been enumerated, as sulphate of alumina and potass, sulphate of alumina and soda, sulphate of alumina and ammonia, the first of which

is the most common; but the alum of commerce is frequently a mixed salt.

Alum is in general obtained in fine large octohedral crystals; has a sweetish, astringent taste; when exposed to a dry atmosphere, it effloresces, but in one of moderate moisture, it does not undergo any change. It is soluble in about 20 parts of cold, and in 3-4ths of its weight of boiling water. The solution is transparent and colourless, and possesses the property of reddening vegetable blues; hence it must contain an excess of acid. When subjected to a moderate heat, it becomes fluid, undergoing watery fusion; and by continuing the heat, the whole of the water is expelled, and a dry, spongy mass is left, commonly called *burnt alum.* If the temperature to which it is exposed is high, part of the acid escapes; the whole of it cannot, however, be expelled, even though the heat is continued.

Different statements have been given of the composition of alum, partly owing to a difference in it, occasioned by the mode of preparation, and partly also to the composition of sulphate of baryta, formed in the analysis, not having been ascertained with accuracy at the time that the experiments were made. They all, however, agree in considering it a triple salt of sulphuric acid, alumina, and potassa, with water of crystallization.

The different analyses are,

	Phillips.	Berzelius.	Thomson.
Acid, -	34.94	34.23	32.8
Alumina, -	11.18	10.86	11.
Potassa, -	10.33	9.81	9.8
Water, -	43.55	45.	46.4

The analysis of Thomson has been frequently repeated, and always with the same result, (First Pr.); so that we may consider it as correct. According to him the alumina and potass are in union with the acid, each forming neutral salts; and considering this the state of combination, he supposes alum to be a compound of

3 atoms sulphate of alumina,	217.5
1 atom sulphate of potass, - -	110
25 atoms of water, - - - -	281.25
its atomic weight being -	608.75

The other varieties of alum, those containing soda and ammonia, have not been accurately analyzed.

The action between alum and carbon is peculiar and important. When exposed to heat with any substance containing it, as vegetable matter, it is decomposed, and a black powder remains, which takes fire when exposed to the atmosphere, from which property, and from its being discovered by Homberg, it is called *Homberg's Pyropherus.*

To procure it, 3 parts of alum and 2 of brown sugar are heated in a ladle, by which they melt and swell considerably. The mixture is then to be well stirred, till it becomes dry, after which it is to be reduced to fine powder, and exposed to a red heat. For this purpose, it must be put into a small phial, the mouth of which is loosely stopped with a plug of clay, and having placed this in a crucible with sand, it is exposed to heat in a fire till a bluish flame appears at the mouth. After allowing this to burn for about five minutes, the crucible must be removed, and the bottle corked as soon as possible.

When the product of this experiment is exposed on a piece of paper to the air, it becomes red hot at different places, which soon spreads over the whole mixture. If a little of it be thrown into a jar of oxigen gas, the combustion becomes more brilliant.

It was lately imagined, that in exposing the alum with the vegetable matter to heat, the acid was decomposed, carbonic acid being evolved, while the sulphur united with the potassa, forming what is commonly called a sulphuret of potass, which was left mixed with charcoal; and that, on exposure to air, the sulphuret rapidly absorbed moisture, and generated heat sufficient to cause inflammation. Since the discovery of the composition of

potassa, it has been supposed that this is also decomposed, and potassium formed, which being in union with the sulphur, may unite with the oxigen either of the air or of its moisture, and thus kindle the charcoal; a supposition sufficiently probable, as it is known that some of the other salts containing potass, particularly when in union with a vegetable alkali, yield the same product; besides, unless the alum contains potass, we fail in getting pyropherus from it.

Alum is decomposed by the alkalies and their carbonates, both of which precipitate alumina, the latter even free from carbonic acid, there being apparently between it and the earth little or no attraction. Hence the method of preparing alumina. To a solution of alum in water, that of the alkaline carbonate is added as long as it will throw down a precipitate, which is then to be well washed, dried, and exposed to a red heat. The alumina thus obtained is not, however, quite pure, still retaining a little potass. To procure it free from impurities, Berzelius recommends that the precipitate should be dissolved in muriatic acid, and again thrown down by ammonia; and Gay Lussac states that he has obtained it pure by decomposing that species of alum which contains ammonia as its alkaline base, merely by heat.

If, after having added potassa to solution of alum, with the view of throwing down the earth, more of it be put in, the precipitate disappears; hence alumina is soluble in potassa, and the same is the case with soda.

Alum is a native production. Alum ores contain, in general, sulphur, iron, alumina, and a small quantity of potass, and from these alum is procured, the process differing in different places. The simplest consists merely in exposing the ore, moistened, to the atmosphere, and stirring it occasionally, so as to present a new surface, by which the whole of the sulphur unites with the oxigen from the air, and becomes sulphuric acid, which then combines with the alumina and potassa to form alum. The remaining part of the process consists in washing the product, filtering, and evaporating, by which crystals are

obtained. In some places the ore is roasted, by burning it with coals or brushwood, and keeping it exposed to heat for a considerable time, by which also the sulphur attracts oxigen, and becomes sulphuric acid, to unite with the alkali and earth. When the ore does not contain potass, some of this must be added, otherwise alum is not formed. For this purpose, the residue of the operation of soap-makers, which contains potassa in union with muriatic acid, is employed, and the alkali of which unites with the sulphuric acid and alumina, to form alum.

Alum is used in large quantity in the arts. When added to tallow, it imparts hardness to it; hence it is used by candle-makers. When a little of it is mixed with milk, it makes the butter separate more quickly; and wood or paper impregnated with it, as by soaking them in its solution, does not easily take fire. It is, however, used chiefly by dyers, in whose operations it serves a double purpose; it opens the pores of the cloth, and makes it fitter to receive the dye-stuff, and its earth unites also with the colouring matter, and thus renders it more fixed. That alumina has a strong attraction for colouring matter is shewn, by mixing solution of alum with that of any colour, as madder or cochineal, and then adding potassa; the alumina is thrown down, taking with it the whole of the colour, with which it is intimately incorporated; and hence a method of preparing some paints.

Other species of alum have been described, but their properties have not been particularly examined, and they are not put to any use.

Aluminated Potass.

It has been already mentioned, that alumina is soluble in the fixed alkalies. The union may be effected by boiling them in water, or by heating them together in a crucible, the former of which is most common. All that is necessary, is to boil solution of potassa on the earth till it ceases to dissolve it, excluding the air to prevent absorption of carbonic acid. The solution called *aluminated*

potass is transparent and colourless. On the addition of an acid, the alkali is neutralized, and the earth is precipitated. The solubility of alumina in potass, forms an excellent method of freeing it from the other earths already described, none of which are acted on by the alkali; and hence a means of analysis frequently resorted to, *(see Mineral Waters.)*

Alumina is a very abundant production of nature. Aluminous fossils have not any characters that can be assigned to the whole of them, they differ so much from each other. Some of the hardest and richest gems are almost entirely composed of it, and the different kinds of clay are nearly of the same composition. The oriental ruby, sapphire, topaz, amethyst, and emerald, belong to this class, all of which contain at least 90 per cent. with a little iron and silica. The oriental sapphire has no less than 98½. The most abundant of the aluminous productions, however, are the clays, among which are porcelain clay and potters' clay, both employed in the manufacture of different sorts of earthen ware. These, along with alumina, contain lime, magnesia, silica, and iron; the fusibility depends on the proportion of alumina, and the colour is imparted by the metal.

SILICUM AND SILICA.

Silica, or, as it is sometimes called, *earth of sea sand*, is, when pure, a white, tasteless, insoluble powder. When subjected to the action of a powerful galvanic battery, it does not undergo any particular change. Davy and Berzelius have, however, succeeded in decomposing it, by passing the vapour of potassium over it, at a red heat, by which potassa was formed, and a black powder was left; and the latter has also decomposed it, by subjecting it to the action of iron heated to redness, (An. de Chim. 81.); and he obtained similar results by the action of potassium on a compound of silica, immediately to be

noticed. To the base thus procured, the names of *silicum*, *silicium*, and *silicon*, have been given; the last adopted by Thomson, because he considers silica an acid, and its base analogous to carbon, or boron.

Silicum is a dark-coloured substance, differing in its properties from the bases of the alkalies and earths. It does not burn when heated in air or oxigen. It is not acted on by water or by acids, except fluoric. It unites with sulphur and chlorine, the sulphuret and chloruret being decomposed by water in the usual way. When heated with the fixed alkalies, it acts on them with detonation, and the same is the case with the alkaline carbonates, carbonic acid being expelled.

Berzelius and Stromeyer have concluded, from experiment, that silica is composed of about 52 of oxigen to 48 of silica; and, in a late paper of the former chemist, the proportions are stated to be 50.3 to 49.7.

Dr Thomson, (First Pr.), from reasoning founded on an examination of the different minerals in which silica exists as an ingredient, and from an analysis of the compounds of this earth and water, concludes that its atomic weight is 20; and as that of oxigen is 10, if he is correct in his conclusion, that of silicum must also be 10; and consequently, silica is composed of equal parts, by weight, of its ingredients.

The only known compound of silicum and oxigen, is silica.

Silica, when pure, is a white tasteless powder, of sp. gr. 2600. It requires a very strong heat for its fusion, that of the oxi-hydrogen blow-pipe being necessary. It is insoluble, water boiled on it not diminishing its weight in the smallest degree. It is well known, however, that, when recently precipitated from some of its solutions, a little of it is dissolved. It seems also to unite with water, and form different hydrates, the ingredients, according to Thomson, being in atomic proportion, (First Pr.)

Silica is not acted on by the simple acidifiable bodies, nor by any of the acids, except fluoric; in this respect differing from the preceding earths.

Fluo-Silicic Gas.

It has been already mentioned, (p. 338.) that when fluor spar is acted on by sulphuric acid, in glass vessels, a gaseous fluid is disengaged, which was at one time supposed to be pure fluoric acid.—It is now known, however, to contain silica, and hence it has been called *silicated* or *siliceo-fluoric*, occasionally also *fluo-silicic* gas. It was discovered by Scheele, and afterwards examined by Priestley, but more lately by Dr Davy, to whom we are indebted for the principal facts concerning it.

It is obtained by pouring sulphuric acid on an equal weight of the powder of the spar, in a glass retort; or, to save the apparatus, a mixture of equal parts of spar and powdered glass may be used. On the application of heat the gas comes off, and may be collected over mercury.

Fluo-silicic gas is transparent and colourless. It is unfit for the support of respiration and combustion. Its sp. gr. is 3500, 100 inches weighing 108 gr. It has a pungent odour, somewhat resembling that of muriatic acid. When exposed to air, dense white fumes appear, owing to its uniting with the moisture. When passed through water it is decomposed, and a white powder is deposited, which is silica in a state of purity, fluoric acid, with a little of the earth, being retained by the fluid. This experiment is easily shewn, by admitting a little water into a jar of it, over mercury, or merely by putting the mouth of the retort from which it is issuing, into it. According to Davy, water consumes about 263 times its bulk of it, the fluid having the properties of a weak fluoric acid.

The composition of this gas, given by Dr Davy, is fluoric acid 37.6, silica 62.4, which very nearly agrees with that mentioned by Thomson, who supposes it to contain an atom of each of its ingredients; in which case it will be composed of acid 38.46, silica 61.54.

Though fluo-silicic gas is by some considered as an acid, Berzelius is of opinion that it is a salt, a *fluate of silica*, differing from others only in being gaseous.

Considering it as a compound of fluoric acid and silica, the chemical changes during its preparation are accounted for, by the fluor spar effecting the decomposition of the water of the oil of vitriol, the oxigen uniting with the calcium to form lime, and the hydrogen with the fluorine to generate fluoric acid, with which the silica enters into union, to produce the gaseous compound. When fluo-silicic gas is brought into contact with salifiable oxidized bases, substances are formed which by some are called *fluo-silicates*, the acid and base having, it is supposed, united to produce a salt. It has been already mentioned, that Berzelius does not admit that the gas is an acid; and he accordingly adopts a different opinion with respect to the nature of the compounds formed by its action on salifiable bodies. He supposes that they are triple compounds of fluoric acid, silica and the base by which it has been acted on, as *fluate of silica and potassa*, &c. (An. de Ch. et de Ph. xxvii.)

The same action takes place with ammonia, for when they are presented to each other in the gaseous state, they form a white saline powder. When, however, an ammoniacal solution is used, the product is different, the fluo-silicic gas undergoing complete decomposition, the whole of the silica being deposited, while the fluoric acid and alkali unite, and form a fluate of ammonia, which remains in solution. The product of the action of the gases on each other, when put into water, also undergoes a similar change. The fluid produced by either of these processes, when boiled in glass vessels, corrodes them, owing to the fluoric acid it contains.

It has been already mentioned, that Berzelius succeeded in procuring silicum by the decomposition of some of the compounds of silica. The one then particularly alluded to, was fluo-silicic gas. When potassium was burned in it, a brownish substance was formed, which, when heated in oxigen, generated fluo-silicic gas and silica, and the residue, when acted on by fluoric acid, yielded also the same gas, itself becoming of a darker

colour. The matter thus procured was considered to be pure silicum. The same results were obtained by heating potassium with dry fluo-silicate of potass, washing the product with water, and again exposing it to heat.

Silica and Alkalies.

The alkalies act powerfully on silica, either in the dry or humid way, and form compounds totally differing in their properties, according to the proportions. When the alkali is in excess, a soluble substance is formed. When, for instance, 3 of carbonate of potass and 1 of silica are heated, the mixture swells, gives off carbonic acid, and lastly yields a transparent vitreous body, called *silicated potassa*, which, on exposure to air, deliquesces, and is soluble in water. When also aqua potassæ is boiled in recently precipitated silica, a transparent solution is obtained, similar in its properties to the former. By exposure to air, carbonic acid is absorbed, and silica is deposited; and the same happens when an acid is added, the alkali being neutralized, and the silica thrown down, but a little of it, it is supposed, is also dissolved. Muriate of ammonia also causes a deposition of the earth.

When, instead of using a large proportion of alkali, the silica is in excess, a substance of a very different nature is produced; the product of their union, in these proportions, being glass.

Glass.

There are different kinds of glass, according to the substances employed in its manufacture, such as bottle glass, flint glass, window, broad, and plate glass.

Bottle glass is in general made by exposing to heat common sea sand, which is almost entirely silica, and the refuse of the operation of soap-makers, which, along with potass, contains a large quantity of lime, with some alumina, magnesia, and silica.

Window glass is formed from sand, and kelp or barilla; and the finer kinds are manufactured from potashes, or soda, and very pure sand, or, which is bet-

ter, powdered flints, these being almost entirely composed of silica.

In the manufacture of glass, the substances are separately reduced to powder, and afterwards well mixed. They are then thrown into a kind of furnace, or oven, and heat applied to them, by which the moisture is expelled, part of the carbonic acid is driven off, and the inflammable substance is consumed; at the same time, an action takes place between the silica and alkaline matter. In this part of the process, which is called *fritting*, great care is taken not to apply too much heat, otherwise a considerable part of the alkali is sent off in vapour; the mixture is also constantly stirred, to allow the whole of the carbonaceous matter to be consumed by its coming in contact with the air, and to prevent it from running into hard lumps. After this, the substance is removed from the furnace, and set aside to cool, in which state it is termed *frit*.

When frit is again to be melted, for the purpose of making glass, it is put into large conical vessels of baked clay, previously heated, each of which holds about 20 cwt. In these it is exposed to a high temperature for about two days, by which the whole becomes fluid, and passes into the state of glass. During this part of the process, a quantity of saline matter collects at the top, called *sandiver*, or *glass-gall*, which is removed by means of iron ladles. After this, the heat is continued, till portions of the glass, when taken out and cooled, do not present a speckled appearance. It is then said to be refined, and its temperature is allowed to fall, till it becomes so thick that it can be wrought into the various articles.

Though silica and the alkalies, by their union, produce glass, other substances are added to make it more perfect, such as the oxids of lead and manganese, and sometimes also a little nitre. Various ingredients are likewise employed, to give it particular qualities.

When glass is prepared from kelp or barilla, it always acquires a greenish tinge, from the iron which they con-

tain. To prevent this, black oxid of manganese is mixed with the fused matter, to afford oxigen to the iron, by which it passes into that state, that it either does not combine with the glass, or if it does, does not colour it. Oxid of manganese itself makes glass purple, but by being deprived by the iron of a portion of its oxigen, it also passes into that condition, that it does not communicate any colour; great care must therefore be taken to add the due quantity, for if too much be employed, the glass will have a purple tinge; whereas, if too little be used, the whole of the iron will not be acted on, and it will retain a little of the green. When too much manganese has been used, which is known by removing a little of the fused matter, and allowing it to cool, it can be easily destroyed by thrusting pieces of wood into it, so as to deprive it of its oxigen, and form carbonic acid, which is expelled by the heat.

Nitre is occasionally also employed for destroying the green tinge communicated by iron, acting in the same way as the manganese, by affording oxigen to it, and causing it to pass into that state that it will not impart colour.

Compounds of lead, such as litharge, are always mixed with the ingredients of glass, proving very powerful fluxes, and thus causing the substances to melt more easily. They also impart greater density, and increase the lustre of the glass; and they make it more tenacious, consequently more easily wrought into the different articles.

If glass, after it has been fused, be hastily cooled, it is easily broken by the slightest agitation. Hence we often find that it cracks without any apparent cause; but this is prevented by the process of *annealing*, to which it is subjected immediately after it is manufactured. Annealing consists in placing the glass in a long oven, the heat of which is considerably below that necessary for its fusion, and which is hotter at one end than the other. The articles are put in at the warmest extremity, and gradually drawn from this to the colder,

and, when almost cold, they are removed. As the first set comes out at the one end, a second is put in at the other, and in this way the oven is kept always full.

During this process, it is supposed that the gradual reduction of temperature allows the particles of the glass to arrange themselves properly; whereas, when quickly cooled, they are prevented from assuming that arrangement, and the slightest cause is sufficient to rend them asunder. On the proper annealing, then, depends entirely its capability of standing sudden applications of heat or cold. That glass which is not annealed is easily broken by exciting a slight vibration in its particles, can be shewn, by forming a tube, and allowing it to cool without annealing. If a small piece of flint be thrown into it, it is instantly broken. The same is the case with the green glass substances, called Rupert's drops, which are formed by allowing the melted glass to fall into water. If the end of the tail be broken off, the vibration excited instantly shatters it to pieces.

It is a remarkable fact in the making of glass, that if the fused matter be allowed to *cool very slowly*, as is the case when the furnace cracks, and its contents escape, it loses entirely its transparency and lustre, and resembles a stony body, becoming much less fusible than before; but if after this it be again melted, and *cooled quickly*, it resumes its former appearance. This has been proved to depend entirely on the quickness with which the matter after fusion passes into the solid state, a piece of green bottle-glass having been made to undergo these changes repeatedly, by fusing it, and at one time making it cool slowly, and at another quickly. It is not known how this acts; the gradual cooling may allow the particles so to arrange themselves, as to make the substance opake, but the difference in fusibility cannot be accounted for.

On this property depends the method of converting glass into what is called *Reaumeur's Porcelain.* For this purpose, after being modelled into any particular article, it is surrounded with a bad conductor of caloric,

as finely sifted ashes, or Paris plaster, and then exposed to heat, less than what is sufficient to melt it, and during the slow cooling, it loses entirely its transparency, becomes less fusible than before, and not so liable to break by a sudden application of heat or cold.

Though glass, as generally made, is transparent and colourless, a variety of colours can be imparted to it, by the addition of metallic compounds. The oxids of the metals, when melted with glass, combine with it, and communicate colour, without diminishing its transparency and lustre, provided they be employed in proper proportion. Those generally used for this purpose, are oxid of gold, which gives a red colour, resembling that of a ruby; iron, which imparts a variety of colours, according to its state of combination. It has been already mentioned, that the green tinge of bottle glass is owing to iron; when in larger quantities, the glass is yellow or brownish. The compounds of copper communicate a green colour, similar to that of an emerald, while antimony gives a yellow. Oxid of manganese, it has been already stated, is added in small quantity to destroy the colour given by iron; but when too much is employed, it imparts a purplish tinge; hence its use in making purple glass, the appearance of which depends entirely on the quantity employed. When glass is fused with compounds of cobalt, it becomes of a rich blue colour; of course, if antimony be employed at the same time, it makes it green, which is produced by the blue of the one and the yellow of the other. The metal called chrome imparts to glass different colours, according to the compound employed, as red and green; and as the colours communicated by it are far superior to those of other metals, it is much used in imitating gems, as emeralds and rubies.

Glass is often rendered opake, forming what is called *enamel*. This is done by the addition of a large quantity of metallic compound, which does not colour it. The most common is oxid of tin, which renders it white and opake, and by the addition of other metallic compounds

to this, different colours may be given it. Another white enamel is formed, by mixing burnt bones with glass, but it is not so fine as that with tin. These enamels are used chiefly as a coating to metals, as in making dials for clocks and watches.

Another process depending on the union of silica with other bodies, is the manufacture of earthen ware, no less interesting in all its stages than that of glass. The substances employed are the different kinds of clay, in which silica exists in large quantity; but it is the alumina which they contain, that gives them the properties that render them fit for this manufacture. Lime also exists in them; but if it be in great quantity, it makes them too fusible, and a little iron is also present, which gives to them a reddish or brown colour. On the purity, then, of the clays, depends the fineness of the earthen ware. The substances used in China are very pure, but in Europe they are in general inferior. In some parts of it, however, very fine clay has been found, and in these earthen ware of a superior quality is made. Magnesia is occasionally added to clay, to prevent, as some suppose, the contraction which it suffers on exposure to heat; but if too much be employed, it adds to the fusibility of the mixture. The coarser kinds of clay are used for inferior articles, as crucibles, grey beards, and brown cans.

In the manufacture of the finer earthen ware, the clay is mixed with siliceous matter, obtained by reducing flints to very fine powder. For this purpose, they are exposed to heat in a kiln, similar to that in which limestone is burned, by which they become brittle, and are easily powdered.

The clay is prepared nearly in the same way, after which it is mixed with water, and well kneaded with wooden instruments till it becomes a uniform mass, in which state it is mixed with the powdered flints, also made into a paste. The mixture, when fluid, is then passed through fine sieves, and poured into brick troughs, in which it is exposed to heat, till, by the expulsion of the water, it becomes of proper consistence. After this,

it is again well kneaded, by beating it with wooden mallets, and working it with the hands, till all air-bubbles disappear. It is then in a condition fit for being moulded into any shape, which is done with the finer kinds of ware, by casting it in moulds, and with the coarser sort, by forming it on a wheel.

The articles thus prepared, are dried either in the air, or in stoves slightly heated, after which they are put into pots of baked clay, and heaped up in a tall oven. A moderate heat is then applied, but which is afterwards gradually increased, and continued for two days and nights; they are then removed, and in this state the ware is called *biscuit*, and to which the figures are generally imparted. For this purpose, an impression from a copperplate is thrown off on thin paper, which is put when moist on the biscuit, and gently struck with a flannel roller, and after remaining on for a short time, it is washed off with a sponge, the impression being communicated to the ware. The colour depends on the substance employed for taking the figure from the engraving. In general, a metallic compound is used, such as one of cobalt, which gives a blue. In some instances the patterns are applied with a hair pencil, the paint being composed of a metallic matter, mixed with a flux and oily substance, which when heated melts, and attaches itself to the ware. The compounds of antimony and silver give a yellow and orange, gold a purple, copper a green, platina a whitish, and iron a red, brown, or black, according to the compound used.

The biscuit, as thus prepared, is very porous, and of course unfit for containing fluids; it is necessary, therefore, to have it covered with a dense body, or *glazing*, as it is called. That commonly used is a mixture of flints and white lead, both reduced to very fine powder, and made into a thin paste with water. Into this the biscuit is dipt, by which it receives a coating, the porosity of the ware making it adhere. When thus covered, they are heaped up on small stands of baked clay, in an oven, and exposed to heat, sufficient to fuse the glazing,

by which it unites with the materials of the biscuit, and communicates a dense coating, having a fine polish, and impervious to water, in which state they are ready for the market.

Silica is the most abundant of the mineral productions. Its fossils can scarcely be distinguished by any particular properties. Some have a great degree of hardness and lustre, but many do not possess these qualities in so remarkable a degree as those of other classes. Quartz, or rock crystal, amethyst, cairngorm, chalcedony, flint, all the varieties of Scotch pebble, jasper, opal, and many others, belong to the siliceous fossils, some of which, as rock crystal and flint, are almost pure silica. Silica is found in other minerals of a more compound nature, as garnet, shoerl, tourmaline, feldspar, and some others. The more compound rocks, as granite, porphyry, and basalt, contain a considerable quantity of it. It occurs, also, in some waters, the most remarkable instance of which is in the boiling fountain of Geyser in Iceland. In this there is a free alkali, but apparently in too small quantity to dissolve the earth, so that the means by which it is kept in solution are not known.

GLUCINUM AND GLUCINA.

Glucina was discovered by Vauquelin in 1798, in the mineral called *beryl*. In obtaining it, the mineral is fused with thrice its weight of potass, and the product dissolved in diluted muriatic acid. The solution is then evaporated to dryness, and the residue again dissolved in water, by which the silica is left, and the glucina and alumina dissolved. Carbonate of potassa is next added as long as there is any precipitation, by which both of the earths are deposited, and on the addition of sulphuric acid they are dissolved, and can be separated by adding solution of sulphate of potassa, by which crystals of alum are formed. The solution contains glucina, with a little alumina, which may be thrown down by car-

bonate of ammonia, and on filtering and evaporating, the excess of the alkaline carbonate is driven off, and glucina is gradually deposited.

That glucina is an oxid has been proved by the experiments of Davy, who, by passing potassium over it, found that potassa was generated; but the base has not been obtained in its separate state. Of course, the name to be given it is *glucinum*.

Glucina, so called from the sweetish taste of some of its compounds, (γλυκυς, *sweet*,) is a white powder, resembling alumina. Its sp. gr. is 2970. It is infusible, and insoluble in water. It unites with the acids, and forms salts, the properties of which have, however, been but little examined. They are almost all decomposed merely by heat, the acid being expelled, and the earth left pure.

Glucina is soluble in the fixed alkalies, in this respect resembling alumina; but it differs from it in being soluble in carbonate of ammonia.

Glucina exists also in the mineral called *Euclase*, which contains, according to Berzelius, 21.78 per cent. while beryl has only about 13. From an examination of these minerals, and of some of the salts, Thomson has fixed the atomic weight at 32.5, and if it is a compound of an atom of each of its ingredients, that of glucinum will be 22.5.

YTTRIUM AND YTTRIA.

Yttria was discovered by Godolin in 1794, in a mineral found in Ytterby in Sweden. For procuring it, dissolve the mineral in nitro-muriatic acid, by the aid of heat, filter, and evaporate to dryness, and expose the residue to a high temperature. Again dissolve and filter, to get quit of silica, and add ammonia, by which yttria, in union with oxid of the metal cerium, is deposited. Expose the precipitate to heat, dissolve in nitric acid, again; evaporate and dissolve, and to the solution add

sulphate of potass, by which oxid of cerium is thrown down. Filter, and add ammonia, and the yttria will fall in the form of a white powder.

Yttria, like other earths, has been proved to contain oxigen, because, when potassium is passed over it, potassa is formed; but the base has not been procured in its separate state. Of course, the name to be given it is *yttrium*.

Yttria, when pure, is a white powder, of specific gravity 4842, destitute of taste and smell, infusible, and insoluble in water.

It unites with the acids, and forms salts, which are decomposed by the alkalies and alkaline earths.

It is not dissolved by the alkalies, in this respect differing from glucina. It is dissolved, however, by carbonate of ammonia, but it requires a large quantity for its solution.

Thomson has fixed the atomic weight of yttria at 52.5, and considering that it is a compound of an atom of each of its ingredients, that of yttrium is considered to be 42.5.

ZIRCONIUM AND ZIRCONIA.

Zirconia was discovered by Klaproth, in the mineral called *zircon*, brought from Ceylon, and it has since been found in *hyacinth*. The process given by Klaproth for procuring it is very simple. The mineral is fused with potassa, then washed and dissolved in muriatic acid; and after being boiled, potassa is added, by which the earth is precipitated.

The process recommended by Dubois, (An. of Ph. N. S. 1.) is more complicated, but yields it purer.

The ore, after being fused with potassa, is repeatedly washed with distilled water, and the insoluble matter, consisting of zirconia, silica, and iron, is dissolved in muriatic acid, and the solution evaporated to dryness. The residue, containing muriate of zirconia and of iron, is dissolved in water; and, by the addition of ammonia, both

of the bases may be precipitated; after which they are boiled with oxalic acid, by which the iron is dissolved, and insoluble oxalate of zirconia formed, which, by a red heat, is decomposed, and the pure earth obtained.

Zirconia thus procured, is a white powder, insipid, inodorous, and insoluble in water. Its sp. gr. is about 4000. When exposed to a strong heat, it is fused, and forms a transparent glass, sufficiently hard to strike fire with steel, and to scratch glass.

Zirconia, as prepared by the process described, is not soluble in acids; but if it be fused with potassa, it may, after this, be dissolved by muriatic acid, and then precipitated by the addition of an alkali, in which state it is a hydrate, and is then easily acted on by acids, and forms salts.

According to Thomson, the atomic weight of zirconia is 60.

The substance described by Berzelius as an earth, under the name of *thorina*, has been found by him to be merely yttria, in union with phosphoric acid, (An. de Ch. et de Ph. xxix.)

END OF VOLUME FIRST.

JOHN PILLANS, PRINTER, EDINBURGH.

Stewart Carson

ELEMENTS

OF

CHEMISTRY.

BY

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ERRATA CORRIGENDA.

Page 40. Line 3. *for* conch *read* gong.
Page 61. Line 16. *for* silver *read* quicksilver.
Page 240. *for* $\frac{43.75}{56.25}$ *read* $\frac{56.25}{43.75}$
Page 249. Line 12. *for* Isaguric *read* Igasuric.

SECTION X.

SUBSTANCES FORMING SALIFIABLE BASES, LONG KNOWN BY THE NAME OF METALLIC OXIDS*.

IRON.

Iron is by far the most abundant and useful of metals. It has been long known, and in use since the earliest ages. When pure, it is of a bluish white colour, has a fibrous texture, and, when polished, considerable lustre. It is superior in hardness to any of the others, and is also very malleable and ductile. It can be drawn to wire of the thickness of a human hair, the tenacity of which is considerable. One of the 1-13th of an inch, will sustain a weight of about 550 pounds without breaking. In drawing iron into wire, by passing it through holes in well-tempered plates, it is usually immersed in weak aquafortis, merely to clean it. It is said, however, to be much better to put it into a weak solution of sulphate of copper or blue vitriol, by which it acquires a very thin coating of copper, which prevents it from being injured by the plate; the copper being easily destroyed by the last annealing, to which of course it is frequently subjected during the process.

* This class includes the substances commonly called *Metals*.

The sp. gr. of iron varies from 7700 to 7800. Its atomic weight is 35.

Iron is remarkable for its magnetic property, being attracted by a magnet; and, by a particular contrivance, it may itself be made magnetic. By entering into union to a certain extent, this property is not only increased, but rendered more fixed; but beyond this, it ceases.—Thus a little sulphur makes it more capable of retaining the magnetic power; but if it be in large quantity, the compound does not affect a needle.

Iron is one of those substances which, by the application of heat, passes through different degrees of hardness. When heated to whiteness, it becomes soft, and very malleable, so that it is easily wrought into different forms. In this state, also, it may be *welded*, that is, if two pieces be put together, and struck forcibly with a hammer, they unite, and the joining is as complete as if it were only one piece. The temperature at which this takes place is at about a full white heat. When above this, iron becomes very brittle, so that it is easily broken; hence the necessity of paying particular attention to the temperature. It melts at 158 W.

When iron is exposed to air, it very soon acquires a brown crust on its surface, called *rust*, which is a carbonate; but this change takes place only when the atmosphere is moist, and is owing, therefore, to the decomposition of the water, the iron acquiring oxigen to form an oxid, which combines with the carbonic acid always existing in the air.

When iron is heated in air, it unites with its oxigen, the facility with which they unite depending on the temperature. When made red hot, black scales are formed, which are easily detached. If in the state of filings it be cast into the flame of a sheet of paper, beautiful sparks are thrown off, which are also an oxid. The scales found around a blacksmith's anvil, are also the same, formed during the process to which the iron is subjected, and which are beat off from it by the hammering.

When iron is heated in oxigen gas, the appearance

presented is very beautiful; the oxigen being quickly absorbed, and a compound of it and the metal formed, (see p. 173. vol. i.) In all of these cases an oxid is generated, possessing in some degree a metallic lustre, but without malleability or ductility.

Different statements have been given of its composition.

It is composed, according to

	Bucholz.	Wollaston.	Berzelius.
iron,	100	100	100
oxigen,	29.83	29	29.5

According to the late experiments of Thomson, (First Pr.) 100 of metal unite with 28.57 of oxigen,

and as 100 : 28.57 :: 35 : 9.99,

so nearly 10, that we may consider it a *protoxid*, composed of

1 atom iron,	35	or 77.78
1 atom oxigen,	10	22.22
its atom being	45	100

It is commonly called the *black oxid*, in which the oxigen is not in sufficient quantity to destroy the magnetic properties.

When protoxid is heated strongly in air, it gradually unites with more oxigen. Or if it be dissolved in nitric acid, by the aid of heat, it absorbs it during its solution, and becomes peroxid, which may be precipitated by ammonia. As thus procured, it is a reddish brown powder, insoluble in water and in nitric acid.

Different statements have also been given of its composition. It is composed, according to

	Bucholz.	Wollaston.	Berzelius.	Thomson.
iron,	100	100	100	100
oxigen,	42	43.5	44.25	42.85

If we consider the statement of Thomson as correct, then the oxigen in the peroxid is a multiple by $1\frac{1}{2}$ of that in the protoxid, and its atomic weight will therefore be $35 + 15 = 50$.

In the union of iron and oxigen, the law of multiple proportions does not hold true, the oxigen in the peroxid not being a multiple by a whole number of that in the protoxid, from which some have supposed that there is another oxid not yet discovered, and in which the proportions will be found to be 100 to 14.28. If so, the oxigen in the black oxid will be twice, and that in the red oxid thrice as much as in the supposed oxid.

Other oxids of iron have been mentioned by different chemists, but the existence of these has not been satisfactorily proved; the only oxids known to unite with acids, and form salts, being those described.

Different statements have been given of the action of iron on water. When they are kept together and exposed at the same time to air, there is a decomposition and disengagement of hydrogen gas, but when the water is pure, the iron may be kept in it without undergoing any change, provided air is excluded. At a high temperature, however, there is a rapid decomposition and evolution of hydrogen, as is shewn by passing its vapour through a red hot gun barrel, or earthen tube stuffed with shavings of iron, (p. 138. vol. i.) by which the metal is converted to protoxid.

The only compounds of any interest of iron and the simple acidifiable bodies, are those with carbon, sulphur, and cyanogen.

Carburet of Iron.

The action between iron and carbon is important, as by their union they form the useful articles *steel* and *cast iron*.

Iron, when extracted from its ores, unites with a little of the carbonaceous matter employed in the process, and forms *cast iron*, of which there are different kinds according to the quantity of carbon. When thin bars of it are kept at a red heat for some time, imbedded in charcoal, they unite, and form steel, which is therefore a *carburet of iron*. Steel is hard and brittle, is of a greyish colour, and susceptible of a high polish, more fusible than iron,

and malleable and ductile. Its most remarkable quality, however, is becoming very hard, when heated and suddenly cooled. This is what is called hardening steel, and the giving it the proper degree of hardness, is termed *tempering*. When heated in this way, it is the hardest of metals, and is also possessed of great elasticity, owing to which it is useful in many operations.

That steel is a compound of iron and carbon, is proved by putting a piece of it into diluted nitrous acid, by which the former is dissolved, and a black powder left, having all the properties of the latter. The quantity of carbon varies according to the process practised in preparing it. In general it is from about 4 to 12 ounces in the 100 weight. The more it contains, it becomes the more fusible; it is of the utmost consequence, therefore, to pay particular attention to its manufacture. In this country, large troughs are built of mason-work, below which fires are placed, so as to heat the whole of them. In these are put alternate layers of charcoal and bars of iron, and when full they are covered with clay. The fires are then kindled, and continued for about 10 or 11 days, during which the materials are kept at a dull red heat. They are extinguished when the iron has combined with a sufficient quantity of carbon, which is known by taking out a bar, and testing it. From the blistered appearance of the article prepared in this way, it is called *blistered steel*. It is used for horse shoes, agricultural instruments, and the like. When steel is hammered, it is very much improved in its properties, and rendered fit for many more purposes. This is done by putting together a number of pieces of blistered steel, bringing them to a red heat, and then hammering them, till they are welded, the hammering and welding being repeated several times. In this state it is called *shear steel*, and is used for making swords, table knives, &c. A still finer kind is called *cast steel*, but different accounts are given of the mode of manufacturing it. It is generally said to be prepared by fusing blistered steel, surrounded by powder of charcoal and glass. According to other

statements, it is fused without any admixture, and when liquid, poured into moulds, and when cold, hammered as in the manufacture of shear steel. Cast steel is much closer in its texture, and harder, than the other kinds; hence it is used for the finer sorts of instruments, as penknives, razors, and surgeons' instruments.

Sulphuret.

Iron unites easily with sulphur, the union being effected in different ways. When 1 of iron filings, and 3 of sulphur, by weight, are heated in a Florence flask, they unite when the latter is properly melted, and at the moment of union, there is a vivid glow over the whole mixture, and which continues for some time. A black matter is left, supposed to be *proto-sulphuret*, the ingredients being in the proportion of iron 63.64, sulphur 36.36. When a plate of iron at a red heat is held on sulphur, there is a union and formation of sulphuret and indeed the action is so violent, that the metal is soon pierced, leaving a hole of the size of the sulphur; but for the success of this experiment, it is necessary to use steel or malleable iron.

Proto-sulphuret of iron is insoluble in water. It is acted on by acids, provided water is present, the iron being oxidated, and sulphuretted hydrogen gas disengaged, and hence it is frequently employed in the preparation of this acid. For this purpose, equal parts of sulphuret and sulphuric acid, mixed with 4 of water, are put into a retort, and the gas collected in the usual way. As the water in this case undergoes decomposition, the hydrogen unites with the sulphur, and the oxigen with the iron, the former coming off, and the latter remaining in the retort, in union with the sulphuric acid.

When proto-sulphuret of iron is exposed to a red heat with more sulphur, a *per-sulphuret* is formed. It is of a yellow colour, and has more lustre than the former. It differs from it in not being affected by acids.

Iron is also acted on by sulphur at a low temperature,

provided moisture is present, and a substance is formed, which, when exposed to air, unites with its oxigen, and leaves the nitrogen, and hence the method by which this elastic fluid is usually procured, (vol. i. p. 206.)

Sulphurets of iron are native productions, well known by the name of *pyrites*, of which there are two kinds, the *magnetic* and *cubical*, the former corresponding to the proto-sulphuret, the latter to the per-sulphuret. The magnetic, when exposed to air and moisture, slowly attracts oxigen, and becomes sulphate, the action in fact being the same as with the mixture in the preparation of nitrogen gas, and hence the mode of preparing the sulphate of iron of commerce. The other pyrites is found in cubical crystals, having considerable lustre, and the properties of the yellow artificial sulphuret.

Salts of Iron.

The acids act very easily with iron, the action differing according to the acid, and its state of concentration. The salts formed, are of course like those of the fixed alkalies and earths, compounds of the acid and iron in a state of oxidation.

Nitrate.

When iron filings are thrown into nitric acid, diluted with an equal quantity of water, the action is violent, nitric oxid in large quantity being disengaged, and the iron passing to the high state of oxidation. In performing this experiment, the filings should be thrown into a glass, standing on a plate of water, and into which the diluted acid has been previously poured, and instantly covered with a shade, to prevent the acid vapour from escaping.

When the acid is more diluted, the metal is gradually dissolved, acquiring oxigen from part of it, and a nitrate is formed. This is of a brownish colour, but does not afford crystals on evaporation. If it be more largely diluted, and pieces of iron put into it, a solution

is slowly formed, which on evaporation yields greenish crystals; the former of these is *per-nitrate*, the latter *proto-nitrate.*

Like metallic salts in general, they are decomposed, particularly the per-nitrate, by alkalies and alkaline carbonates. The action with the carbonate is important, as it affords a pharmaceutical preparation, much used as a tonic, the *liquor ferri alcalini* of the London pharmacopœia.

Two drachms of iron filings are put into two ounces of nitric acid, diluted with six ounces of water, and when the action ceases, solution of carbonate of potass, to the extent of about six ounces, must be added, or till the precipitate formed ceases to be re-dissolved.

In the first part of the process, a per-nitrate of iron, but with a large excess of acid, is formed; and in the second, this excess is merely saturated by the alkaline solution, a part of the iron being precipitated in the state of carbonate, but which is instantly dissolved by the nitric acid, so that the product is a mixture of nitrates of iron and of potass.

Carbonate.

When iron filings are kept in carbonic acid water, in close vessels, they attract oxigen, and then unite with the acid. The fluid acquires a styptic taste; and, on exposure to air, deposits carbonate of iron, having existed in the fluid as a super-carbonate. Rust of iron is also a carbonate, the metal, when exposed to air and moisture, first getting oxigen from the water, and afterwards carbonic acid from the atmosphere; and hence the old method of preparing carbonate of iron, merely by keeping moistened filings exposed to the air.

Carbonate of iron may be more easily prepared, by the decomposition of a soluble salt of iron by an alkaline carbonate. *(See Sulphate.)*

Carbonate of iron is usually in the form of a brown powder, insoluble in water. When exposed to heat, its acid is expelled, and the oxid left pure. Like carbonates,

it effervesces with acids, by which the carbonic acid is driven off.

It is used as a tonic in the dose of about 10 grains, once or twice a day, in general in conjunction with other tonics.

Sulphate.

When iron filings are put into concentrated sulphuric acid, there is no action at a natural temperature; but on the application of heat, part of the acid is disengaged, the metal acquiring oxigen from it, and forming an oxid which enters into union with the remainder of the acid, and produces a sulphate. If, instead of using concentrated, diluted acid be employed, the action is different, the metal acquiring oxigen from the water, and becoming an oxid, which unites with the acid, while hydrogen gas is disengaged, and hence the method generally practised for procuring it. For this purpose equal weights of acid and iron filings, with four of water, are used, the mixture being put into a retort, and the action allowed to go on spontaneously, for, during the union of the fluids, heat is generated, by which the evolution of gas is favoured. The hydrogen obtained in this way is not pure; it burns with a greenish tinge, and is of greater specific gravity than when procured by other means, owing to impurities derived from the materials employed in its preparation.

The solution left in the retort, on evaporation, affords green-coloured crystals of *sulphate of iron*, containing the protoxid.

Proto-sulphate of iron thus procured, is obtained in well-formed rhombic crystals, and is the same with the well-known salt of commerce called *green vitriol*, or *copperas*, but it is seldom prepared in this way. It has been already mentioned, that when the native ores containing sulphur and iron are exposed to a moist atmosphere, they absorb oxigen, and become sulphate; hence, then, the method by which sulphate of commerce is procured, merely by exposure of the ore to air and moisture, being fre-

quently turned up to present a fresh surface. It is then dissolved, filtered, and evaporated.

The different statements of the composition of this salt, all very nearly agree. According to Thomson, it is composed of

acid,	28.9 or	1 atom	= 50
protoxid,	25.7	1 atom	= 45
water,	45.4	7 atoms	= 78.75
	100	its atom being	173.75.

When exposed to heat, it at first undergoes watery fusion, and after the expulsion of the whole of the water, a white mass is left, the *sulphas ferri exsiccatus* of the pharmacopœia. If, after this, the heat be continued, it undergoes decomposition; a weak acidulous fluid is at first given off, and then a fuming acid comes over, known by the name of *glacial oil of vitriol.* Hence the method of preparing this acid now generally practised on the continent. For this purpose the salt, previously freed of water of crystallization, is put into cast-iron retorts, having receivers adapted to them, and kept cool. On the application of heat, the acid fluid comes off, and is condensed in the receiver. After the action has ceased, there is left in the retort a powder of a reddish colour, and which is per-oxid of iron; so that, during the expulsion of the acid, part of it has undergone decomposition, and given off oxigen to the protoxid, to convert it to per-oxid, and hence the origin of the sulphurous acid also evolved during the process. The residue in the retort is commonly sold under the name of *colcothar*, and is used for making razor straps, and for polishing metals. As the acid obtained in this process is of an oily consistence, and being prepared from green vitriol, hence the name *oil of vitriol.*

The process for procuring anhydrous sulphuric acid from the sulphate, has been described, vol. i. p. 312.

Sulphate of iron is soluble in about 6 of temperate water, affording a solution of a pale green colour, which, on exposure to air, is gradually changed, absorbing oxi-

gen, by which the metal passes to a higher state of oxidation, and becomes a *per-sulphate;* but, as the acid is not in sufficient quantity to keep the oxid in solution, part of it is deposited in the form of a yellowish brown powder.

The alkalies and their carbonates decompose the sulphate, throwing down either the oxid or carbonate. With the latter the action is important, as affording a method of preparing carbonate of iron, which is a pharmaceutical process. For this purpose, to a solution of four ounces of sulphate of iron, add that of five ounces of carbonate of soda. A dark-coloured precipitate is formed, which is to be exposed to air, and afterwards well washed and dried. It is at first a proto-carbonate, but by absorption of oxigen and carbonic acid, is gradually converted to per-carbonate.

Sulphate of iron is used for yielding oil of vitriol and colcothar. It affords also a solution of per-sulphate, which is much employed in striking a dark colour with vegetable astringent matter, and hence its use in dyeing and in making ink. *(See Dyeing and Tannin.)*

Muriate.

Muriatic acid acts easily on iron, the action being the same as with diluted sulphuric acid, by which hydrogen is disengaged, and *proto-muriate* of iron formed. The solution is of a greenish colour, but is very apt to undergo decomposition by exposure to air, oxigen being absorbed, and the salt becoming *per-muriate.*

Per-muriate, with the maximum oxid, may be prepared also by dissolving that oxid, or the carbonate, in the acid. It is brownish, and does not crystallize, but yields, on evaporation, a yellow-coloured mass, deliquescent on exposure to air.

Muriate of iron is much employed in medicine as a tonic, chiefly in the form of tincture. The process given by the Edinburgh College, consists in dissolving the black oxid in the acid, and afterwards adding alcohol, while in the London Pharmacopœia, the red oxid, and in the Dublin, the carbonate is ordered. The muriate pre-

pared from these is the same; for though the Edinburgh process yields at first a proto-muriate, it very quickly becomes per-muriate.

The alkalies do not act on iron, at least if there is any action, it is very trifling.

Iron is a very abundant production of nature. It has been found, in a few places, in its *native* state, that is, metallic. In Siberia there is a mass calculated to weigh about 1600 pounds, and in Peru there is another of about 300 pounds. The source of these immense masses is not known, but it is supposed that they are meteoric,—a supposition deriving plausibility from the fact that they resemble, in their chemical composition, substances of undoubted meteoric origin, particularly in containing nickel, cobalt, and some other ingredients, always found in meteoric stones. Two pieces have also been observed at Baffin's Bay, having the same composition as those of Siberia and Peru.

Iron exists, however, in greatest abundance in combination, particularly in union with sulphur and with oxigen, and from which it is always procured.

The methods practised for procuring iron from its ores, are nearly the same in all places; the substances used in the reduction, are coke and charcoal, the latter being preferred, but, from its scarcity in this country, is not much used. The first process to which the ironstone is submitted, is to break it to small pieces, and roast it, by which the sulphur and carbonic acid are expelled, and the iron is left in union with oxigen; it is then *reduced*, by mixing it with coke and lime, and subjecting it to a strong heat in a furnace, by which the charcoal unites with the oxigen to form carbonic acid, which is disengaged, and the iron is left in its metallic state; the lime acting on the earthy impurities of the ore, and fusing them. When the iron is completely deprived of its oxigen, it is melted and falls through the mixture, to the bottom of the furnace, and is then run off into cavities made in sand, forming *pig iron;* and it is in this state also that it is drawn off into moulds, to yield the

different articles of *cast iron.* As cast iron is very brittle, it is unfit for many of the purposes for which the pure metal is employed; it is therefore submitted to the process of refining, which consists in again melting it, and when cold, subjecting it to *hammering*, to free it from impurities. These processes of fusing and hammering are repeated several times, by which the whole of the carbonaceous matter is expelled, and it is thus converted into *bar* or *malleable* iron, (Aiken's Chem. Dict.)

Ferro-Cyanic Acid.

Cyanogen enters into union with iron, and forms a substance of a peculiar nature, which exists in the pigment long known by the name of *Prussian Blue.*

The method of preparing it was not known till Woodward published an account of it in 1724, (Ph. Tr. 1724.) It consists in mixing four parts of bullock's blood with an equal quantity of carbonate of potass, and after subjecting them to a moderate heat till the mixture becomes dry, raising the temperature till fumes cease to be disengaged. The residuum is then boiled in water, and filtered, and to the fluid is added a solution of 1 ounce of green vitriol and 2 of alum, by which a greenish powder is precipitated, but which, by being washed with muriatic acid, becomes blue.

When baryta is boiled with Prussian Blue, it forms a soluble salt, consisting of the earth in union with an acid, now called *ferro-cyanic acid*, and from which the acid can be disengaged by the addition of oil of vitriol, the baryta being precipitated, and the ferro-cyanic acid left in solution. *(See Fer. Cyan. Bar.)*

Ferro-cyanic acid is a transparent fluid, of a pale yellowish colour, but destitute of smell. It is easily decomposed by light, by which hydro-cyanic acid is formed, and a powder falls, at first of a whitish colour, but soon becoming blue. It is also decomposed by heat, hydro-cyanic acid and hydro-cyanate of iron being formed.

Very different opinions are entertained with respect to the composition of ferro-cyanic acid. Berzelius has sup-

posed it merely hydro-cyanic acid in union with protoxid of iron, but having an excess of acid, an opinion disproved by the experiments of Porret, (Ph. Tr. 1814.), who has found that the iron which ferro-cyanates always contain, exists as an ingredient in the acid; for, on decomposing them by galvanism, the iron is drawn towards the positive pole, along with the other acid ingredients.

According to Porret, ferro-cyanic acid is composed of 2 atoms of hydro-cyanic acid, 2 of carbon, and 1 of iron in its metallic state. The analysis of Robiquet, on the contrary, would lead us to suppose that it is a compound of hydrogen, cyanogen, and iron, and that these are in certain atomic proportions, either forming hydro-cyanic acid and cyanuret of iron, which together constitute the compound acid, or the iron and cyanogen may be considered as united, forming a compound radical, with which the hydrogen is combined, thus constituting a hydr-acid; so that the proper name is *hydro-ferro-cyanic acid.*

Adopting the above as its composition, its ingredients are,

iron,	-	1 atom
cyanogen,	-	3 atoms
hydrogen,	-	2 atoms

the two first united to form 1 atom of the base, with which the 2 atoms of the hydrogen are combined. So that it may be stated to consist of

1 atom ferro-cyanuret	=	iron	1	= 35
		cyanogen	8	= 94.5
2 atoms hydrogen	=			2.5
its atomic weight being				132.

If this opinion, with respect to the composition of the acid, be adopted, two views may be entertained of the nature of the compounds formed by its action on salifiable bases. They may be salts of the acid and metallic oxid, or they may contain the radical of the acid united with the metal in its metallic state, the hydrogen of the former and oxigen of the latter having combined to form water. Of course, when the substance is in solution, it is a compound of acid and oxid.

The salts formed by the action of ferro-cyanic acid and bases, were long known by the name of *Triple Prussiates*, from an idea that they contained an acid in union with a base, and iron *. They are now generally termed *ferro-cyanates*, or *hydro-ferro-cyanates*. They form a very interesting class of compounds, the properties of which have been examined by Porret, (Ph. Tr. 1814.)—Henry, (Nic. Jour. iii.)—Robiquet, (An. de Chem. et de Ph. xvii.)—and Berzelius, (An. of Phil. N. S. 1.)

Ferro-cyanate of Potass.—It has been already mentioned, that, by burning blood with potass, a substance is obtained, which, when mixed with solution of green vitriol, gives a bluish precipitate. From this ferro-cyanate of potassa can be obtained, by throwing it into solution of the alkali, till the fluid ceases to be alkaline, having previously washed the blue with sulphuric acid, to remove the alumina. Oxid of iron is deposited, and the acid is left in union with the potassa. By filtration and evaporation, cubical crystals of ferro-cyanate are formed. According to Porret, they are composed of

44.53 acid,
40.34 alkali,
15.13 water.

It is probably a compound of

1 atom acid,	132	or	48
2 atoms potass,	120		43.8
2 atoms water,	22.5		8.2
	274.5		100

Ferro-cyanate of potassa is soluble in about 3 of cold, and in its own weight of boiling water. When heated slightly, it loses its water of crystallization; but if the heat be strong, it is decomposed; hydro-cyanic (prussic)

* Hence the name *prussic* acid, given to that procured by the decomposition of some of the prussiates, and which was supposed to be the one existing in the salt. It is now known, however, that, during the action there is a decomposition by which hydro-cyanic is given off, so that *prussic* and *hydro-cyanic* acid are the same.

acid, ammonia, carbonic oxid and acid, and carburetted hydrogen are disengaged, and metallic iron, carbon, and potassa, probably in union with cyanogen, remain.

It is decomposed also when heated with sulphur, and sulpho-cyanic acid is formed. Hence the method for procuring it, alluded to in vol. i. p. 343. Equal weights of powder of ferro-cyanate and flowers of sulphur are heated together for some time in a flask. The residue, when cold, is dissolved in water, and by the addition of potassa, any iron in solution is deposited, and the alkali is left united with the sulpho-cyanic acid, and from which the latter can be obtained by distilling it with oil of vitriol. In this instance, sulpho-cyanic acid, which is supposed to be a compound of cyanogen, hydrogen, and sulphur, must be formed by the sulphur deriving cyanogen and hydrogen from the ferro-cyanate, both of which are known to exist in it.

Ferro-cyanate of potass is decomposed by the stronger acids, as nitric, sulphuric, and muriatic, which throw down a whitish precipitate, and disengage hydro-cyanic acid; and hence a method of procuring it in the gaseous form. For this purpose the crystals are placed into a retort, along with a little diluted sulphuric acid, and heat applied, by which the acid unites with the alkali, and the ferro-cyanic acid disengaged, but decomposed, giving off hydro-cyanic acid, which comes over in the form of gas, and must be collected over mercury.

Ferro-cyanate of potass is not acted on by alkalies, or alkaline salts. Some of the earthy salts decompose it, with the earth of which its acid combines. With the salts of iron, the action is very important. When added to these, a precipitate is formed, the colour of which depends on the state of oxidation of the metal. With the proto-salts it is white, but with per-salts it is blue. With the solutions of other metallic salts, precipitates are also in general formed, the colour differing in different cases. *(See Appendix.)*

When anhydrous ferro-cyanate of potass is mixed with the substance called oxid of manganese, the oxigen

from the latter is transferred to the cyanogen in the former, by which *cyanic* acid is generated, and is left in union with the alkali. This is the method recommended by Wohler, formerly alluded to, (vol. i. p. 325.) for preparing cyanates, (An. de Ch. et de Ph. xxvii.) For this purpose equal weights of the dry salt and oxid are calcined at a dull red heat, and the residue digested in alcohol, by which a solution is obtained that will yield crystals when it cools. From this cyanate, the acid may be transferred by double decomposition to other bases.

Ferro-cyanate of the other alkalies, and of the alkaline earths, may be prepared in the same way as ferro-cyanate of potassa, and in their general properties are very nearly the same. The only one of any interest, is that of baryta; because from it ferro-cyanic acid is procured. For this purpose, the salt prepared by mixing Prussian blue with solution of baryta, is dissolved in water, and sulphuric acid is added as long as it throws down a precipitate, which is sulphate of baryta. By filtration, the acid is obtained pure.

Ferro-Cyanate of Iron. It has been already mentioned, that when ferro-cyanate of potassa is mixed with proto-salt of iron, a white ferro-cyanate is precipitated; but when a per-salt is used, the precipitate is blue. The latter is the only one of any interest; it is Prussian blue, the method of preparing which has been already described, (vol. ii. p. 13.) To shew the action of the alkaline ferro-cyanate on the salt of iron, a solution of green vitriol, which has been kept exposed to air, and become a per-salt, ought to be used; and to render the blue deeper, a few drops of muriatic acid should be added to the solution.

Chemists are by no means agreed with respect to the composition of this substance. According to Porret and Vauquelin, it is composed of ferro-cyanic acid and oxid of iron; but Gay Lussac considers it a compound of cyanogen and iron, and therefore a *cyanuret*. If we adopt the view of the composition of ferro-cyanic acid already given, (vol. ii. p. 14.) and that, like hydr-acids, it is decom-

posed by the bases, the oxigen of which is not held by a strong affinity, we must consider Prussian blue as containing metallic iron, and the compound radical of the acid; and if so, during its preparation, the sulphuric acid of the green vitriol and the potassa of the ferro-cyanate will form a sulphate, while the oxigen of the iron and hydrogen of the hydro-ferro-cyanic acid will generate water, leaving the ferro-cyanuret to unite with the iron of the oxid, to produce *ferro-cyanuret of iron*, or Prussian blue.

With respect to the chemical changes during the manufacture of Prussian blue of commerce, the blood, by its incineration, will yield cyanogen, by the union of part of its carbon and nitrogen; and which, as potassa is present, is prevented from escaping; and on mixing the product with the solution of green vitriol, the cyanogen and part of the iron form ferro-cyanuret, which, by its action on the remainder of the metal, produce the Prussian blue. The use of the alum is to render the blue more permanent, when employed as a dye-stuff; for the excess of potassa with which the blood is burned, causes the precipitation of alumina along with the ferro-cyanuret. The intention of washing with muriatic acid, is to carry off impurities, and to heighten the colour.

Prussian Blue is decomposed by a strong heat, a gaseous fluid is given off, and hydro-cyanate of ammonia is sublimed, while oxid of iron remains. It is insoluble in water, and in acids; but by the latter it is decomposed at an elevated temperature. It is decomposed, as already stated, by alkalies and alkaline earths, by which ferro-cyanates are formed, and oxid of iron precipitated.

Owing to the ease with which ferro-cyanates act on the salts of iron, they are used as tests of it, particularly those of potassa and lime. *(See Mineral Waters.)*

The action between Prussian blue and some of the oxids of the metals is peculiar and interesting, particularly with that of mercury, as a substance is formed, by the decomposition of which, cyanogen and hydro-cyanic acid are prepared. When peroxid of mercury is boiled with

Prussian blue, a solution is obtained, which, on evaporation, yields a compound commonly called *Prussiate*, but now more properly termed *Cyanuret of Mercury*.

In this instance, considering the Prussian blue as ferro-cyanuret of iron, there is a decomposition of the water; the oxigen uniting with the iron to form an oxid, which is precipitated, while the hydrogen and part of the cyanogen generate hydro-cyanic acid, to combine with the oxid of mercury, and produce a hydro-cyanate. When this is dried by evaporation, it becomes cyanuret, the 2 atoms of oxigen of the oxid, and the 2 of hydrogen of the acid, coming off in the form of water.

This substance is easily decomposed by heat and by acids, by the former of which cyanogen, and by the latter hydro-cyanic acid, are set free. In the preparation of the mercurial compound, great attention must be paid, otherwise a substance is apt to be generated which does not yield pure cyanogen or acid. The process given by Gay Lussac, (An. of Ph. vii. and viii.) consists in digesting red oxid of mercury with twice its weight of Prussian blue. A solution is formed, which, on evaporation, yields prismatic crystals; but before evaporating, it must be deprived of any excess of iron that it may contain, by digestion with a little more oxid of mercury, and then neutralizing the oxid by muriatic acid. On evaporation, prismatic crystals of cyanuret of mercury are deposited.

Instead of employing Prussian blue of commerce, it is better to use that prepared by the addition of ferro-cyanate of potass to sulphate of iron. Two parts of it may be boiled with three of the red oxid in water, till the insoluble matter becomes quite brown. The solution is then to be filtered, and evaporated to dryness.

For procuring cyanogen, the cyanuret, carefully dried at a temperature little below 212, must be placed into a retort, and the heat of a spirit-lamp applied, by which cyanogen gas is expelled, and may be collected over mercury; at the same time a little cyanuret of mercury comes over in vapour, and is condensed. A black carbo-

naceous-looking matter is left in the retort. In this experiment, the cyanuret is decomposed by the heat, part of the cyanogen being driven off, and the mercury, still retaining some of it, coming off in vapour.

In preparing cyanogen, it is of the utmost consequence that the cyanuret be quite free from moisture; for if any water is present, hydro-cyanic acid, carbonic acid, and ammonia, are the results; part of the cyanogen, without undergoing decomposition, uniting with hydrogen, while another part, being decomposed, gives its ingredients, nitrogen and carbon, to the hydrogen and oxigen, to produce the ammonia and carbonic acid.

Cyanuret of mercury, it has been already mentioned, is decomposed by muriatic acid, and hydro-cyanic acid is liberated. Hence the method of procuring it. Different processes have been recommended, according to the use to which the acid is to be applied. The process given by Gay Lussac (An. of Ph. vii.) is the following. The cyanuret, with muriatic acid in less quantity than is necessary for the neutralization of the mercury, are put into a retort, to the neck of which there is adapted a tube about two feet in length, 1-3d next the retort being stuffed with marble, the remainder with fused muriate of lime, (Chlorid of Calcium.) To the end of the tube there is luted a receiver, kept cool by a freezing mixture. On the application of heat, hydro-cyanic acid vapour, water, and muriatic acid come off, the last of which is retained by the marble, the second by the fused salt, while the acid flows on, and is condensed in the receiver. Here the water in the muriatic acid gives oxigen to the mercury, and hydrogen to the cyanogen; so that hydro-cyanic acid and muriate of mercury are the products.

The fluid obtained by this process is the concentrated acid, the properties of which have been described, (vol. i. p. 341.) As it is used in its diluted state for medicinal purposes, there is no necessity for having recourse to the complicated apparatus of Gay Lussac, a retort and receiver will answer equally well. As, however, the

acid is a very powerful agent, it is necessary to be cautious in the preparation of it, so as to have it always of a certain strength. The process followed at the London Apothecaries' Hall consists in placing into a retort,

Cyanuret of mercury, -	1 part;
Muriatic acid, (sp. gr. 1150)	1 part;
Water, - - -	6 parts.

Having adapted a receiver, heat is applied, and the distillation continued as long as acid comes over; the product is of sp. gr. 0.995. When prepared, it must be kept in earthenware bottles, so as to exclude it from light, to prevent it undergoing decomposition.

Another method of decomposing the cyanuret, so as to obtain from it hydro-cyanic acid, is to pass a stream of sulphuretted hydrogen over it, placed in a tube, the end of which terminates in a receiver, kept cool by a freezing mixture. In this case the mercury retains the sulphur, while the hydrogen and cyanogen unite and form the acid, which coming off into the cool receiver, is condensed. If the cyanuret be dissolved in water, and a stream of sulphuretted hydrogen be passed through it, sulphuret of mercury is deposited, and hydro-cyanic acid is left in solution; and hence another method of procuring it, and by using certain proportions of cyanuret and water, an acid of known strength may always be obtained.

COPPER.

Copper has been longer known than any of the metals. Before iron was used, it was employed in the manufacture of various articles. It is of a reddish colour, has considerable lustre, and acquires by friction a peculiar odour. It has also considerable malleability and ductility. A wire of the 1-13th part of an inch in thickness, will sustain a weight of about 300 pounds without breaking. Its sp. gr. is 800. Its atomic weight 80.

When copper is heated in close vessels, to about 30 of Wedgewood, (4977 of F.) it melts, and its surface becomes of a fine green colour.

When it is heated slightly in contact with air, it is tarnished, and acquires different colours, according to the continuance of the heat. If it be kept for some time red hot, a dark brown crust is formed, which scales off, and is supplied by another. If highly polished, and heated, it assumes various colours, according to the time that the heat is applied; it at first becomes blue, then yellow, and afterwards violet; in which states it is employed for ornamenting toys. When subjected to a very intense heat, as when exposed to the oxi-hydrogen blowpipe, it burns with a green flame.

Oxids.

Copper unites with two proportions of oxigen. The *protoxid* is, when artificially prepared, of a reddish colour. It has been examined particularly by Chenevix. It may be prepared by dissolving the metal in muriatic acid, and keeping the solution over copper filings, and excluded from air. On the addition of potassa, the oxid is precipitated of an orange colour, but soon becomes red. It is composed of

copper, 100 = 1 atom = 80
oxigen, 12.5 = 1 atom = 10

and its atomic weight is therefore 90

When first precipitated, it is a *hydrate*, but it is difficult to keep it in the state of protoxid, it absorbs oxigen so easily from the air.

Peroxid may be procured by heating the scales to redness, or by dissolving the metal in nitric acid, and precipitating by an alkali. As thus obtained, it is a blue hydrated peroxid, but on the application of heat, the water is expelled, and it becomes black. Its composition is

copper, 100 = 1 atom = 80
oxigen, 25 = 2 atoms = 20

and its atomic weight is therefore 100

The oxids of copper are not reduced by heat alone; they

require the presence of inflammable matter. They have a strong attraction for water; and hence it is that, when precipitated, they are in the state of hydrate.

Copper has no action with water. It does not even decompose it at a red heat. When exposed, however, to air and moisture, it acquires a greenish crust, which is a *carbonate*, the action being exactly the same as with iron, the metal first acquiring oxigen, and then uniting with carbonic acid.

The action between copper and the simple acidifiable bodies does not present any thing interesting.

The acids in general act very easily with copper. The salts are usually of a bluish colour, and contain, in general, the peroxid.

Nitrate.

Nitric acid, either concentrated or diluted, acts very powerfully on copper; and the action is important, not only as a means of preparing nitrate, but also of procuring nitric oxid. For this purpose, pieces of copper being put into a retort, the acid diluted with 2 of water is poured on, and a very slight heat applied; but when the action commences, it must be discontinued. Part of the acid undergoes decomposition, the copper combines with as much oxigen as will form it into peroxid, with which the remainder instantly unites, while that deprived of its oxigen comes off in the form of nitric oxid, and may be collected over a water trough. There remains in the retort a blue solution, which, on evaporation, yields crystals of nitrate.

Nitrate of copper has a disagreeable taste, is deliquescent, and undergoes watery fusion; when heated strongly, its acid is expelled, and the oxid left pure. On the addition of alkalies and alkaline carbonates, oxid or carbonate is precipitated.

It is composed of

2 atoms acid, -	135
1 atom per-oxid,	100
14 atoms water,	157.5
so that it is a *bi-nitrate.*	392.5

Carbonate.

It has been already mentioned, that copper is converted to carbonate by exposure to air and moisture. The easiest mode of preparing the carbonate, is by the addition of an alkaline carbonate to a salt of copper, by which a bluish precipitate is formed, and which, when dried by exposure to the sun's rays, is a pure per-carbonate.

Sulphate.

By far the most interesting salt of copper is the *sulphate*, better known by the name of *blue vitriol.* Though sulphuric acid can dissolve copper, the sulphate is not prepared in this way; it is always procured by a process similar to that by which green vitriol is manufactured, by exposing the natural ores containing sulphur and copper to air, after being moistened, by which both absorb oxigen, the one to become sulphuric acid, and the other oxid of copper, and which unite to produce the sulphate, or blue vitriol. After it has been exposed to air for some time, the residue is washed, the solution filtered and evaporated, by which crystals are produced.

As thus obtained, it is of a fine blue colour, having a disagreeable taste; when exposed to air, it acquires a whitish crust on its surface, from its losing its water of crystallization. It is soluble in water, forming a blue solution, and which is easily decomposed by the alkalies, the action with ammonia being peculiar. If to its solution a few drops of aqua ammoniæ be added, a powder is thrown down, which is the oxid of copper; but if more be put in, the powder is dissolved, and the fluid becomes transparent, and of a fine blue colour.

By the application of heat, sulphate of copper is completely decomposed, the whole of the acid being expelled, and the oxid left pure. It is composed of

acid,	32	2 atoms	100
oxid,	32	1 atom	100
water,	36	20 atoms	112.5
			312.5

so that it is a *bi-sulphate.*

There does not appear to be any sulphate containing the protoxid.

Copper has the property of forming triple salts with sulphuric acid and the alkalies, particularly with ammonia. The substance called in the Pharmacopœia *ammoniaretum cupri*, is a sulphate, according to Berzelius, *sub-sulphate of copper and ammonia.* It is prepared by triturating 2 of sulphate of copper, and 3 of sub-carbonate of ammonia, till the mixture, which at first becomes moist, ceases to effervesce. Hence the carbonic acid is disengaged, while the 2 atoms of sulphuric acid are left in union with both of the bases. The cause of the mixture becoming moist, is the substance not requiring the whole of the water of crystallization of both salts, part of which is therefore set free. The product is of a deep blue colour, is soluble in water, giving a rich blue solution.

Sulphuretted hydrogen, passed through a solution of sulphate of copper, gives a black precipitate, and which must be considered a sulphuret.

Arsenite.

When solution of arsenite of potass is mixed with that of blue vitriol, there is a double decomposition, and precipitation of arsenite of copper. This substance is of a grass green colour, and is well known by the name of *Scheele's Green*, being employed as a paint. From the ease with which blue vitriol acts on arsenous acid, when in combination, it has been recommended as a test of arsenic when administered as a poison ; but it is not now trusted to, other substances giving precipitates with it, which it is difficult to distinguish from those containing arsenic.

Ferro-cyanate.

On the addition of ferro-cyanate of potass to a salt of copper, a brown-coloured precipitate is formed ; and hence this substance is used as a test of copper.

The alkalies act on copper. Potassa digested on it acquires a bluish colour. When ammonia is kept on the

filings, air being excluded, it continues colourless, but on the admission of air it becomes blue. In the first instance, a solution of protoxid is formed, but which, by exposure to air, rapidly attracts oxigen, and becomes per-oxid, giving the blue solution. If the fluid be again put into the phial on the filings, in the course of a few days it again becomes colourless, the metal depriving the peroxid of part of its oxigen, and thus forming itself and the other to protoxid. These changes may be effected any number of times, taking care to have a sufficient quantity of filings.

Ammonia, it has been already mentioned, throws down precipitates from the salts of copper, and which are redissolved. Hence the use of ammonia in separating this metal from others with which it may be mixed.

Copper unites with iron, but the union is effected with difficulty; the alloy is grey, less fusible than copper, and magnetic.

Iron throws down copper from a solution of any of its salts. Thus, when a plate of iron is put into a solution of blue vitriol, it is very soon covered with a thin coating of copper. Here the iron decomposes the salt; it takes the oxigen from it, by which it is converted to an oxid, and unites with the acid, so that the copper, being brought to its metallic state, is deposited.

Copper is not an abundant production. It is found occasionally, though rarely, in its metallic state. In general, it is in union with oxigen or sulphur, and sometimes also with other metals. The ore from which it is chiefly obtained, is the sulphuret, found principally in Cornwall, Anglesea, and Hungary. In procuring it, it is first broken to small pieces, and roasted, to drive off the sulphur and arsenic, which it frequently also contains. It is then put into a furnace and melted, being occasionally mixed with a little lime, to increase the fusibility, and when fluid, it is drawn off through a hole in the bottom of the furnace, and put into water, by which it is *granulated*, or reduced to coarse powder. The copper thus obtained, is kept at a low red heat for some days, and is, after this, repeatedly fused

and cast into moulds; and lastly, it is placed in a refining furnace with a little charcoal, and again melted, after which, if it bear hammering, it is fit for sale.

Copper, in a state of considerable purity, is occasionally procured also from the springs which contain it. For this purpose, pieces of iron are thrown in, and left there for some time, by which they are dissolved, and the copper deposited in their place; so that they appear to be converted to it, the action being here the same as that already noticed, the iron taking oxigen from the salt, and combining with its acid to form a soluble compound, while the copper in its metallic state is deposited.

Though the atomic weight of copper has been stated as 80, yet some chemists, particularly Dr Thomson, are inclined to consider it as only 40. If so, the atomic composition of the compounds mentioned will be different from those given. Thus, instead of the oxids being considered, the one a compound atom to atom, and the other 1 to 2, that called the protoxid will be a *sub-oxid*, consisting of

2 of copper = 80
1 of oxigen = 10;

and the peroxid must be a compound of

1 atom copper 40
1 of oxigen 10

The salts, instead of consisting of 2 atoms of acid and 1 of oxid, will consist of an atom of each.

The reason for adopting this atomic number is to get quit of the anomaly of the salts of copper containing 2 atoms of acid; but in doing this, many of the other compounds, which, if 80 be taken as the atomic weight, consist of atom to atom, will become compounds of 2 atoms of the metal to 1 of the other substance; so that an anomaly, as remarkable as the one we wish to get quit of, is introduced; besides, by considering the salts as containing 2 atoms of acid, we can more easily conceive why ammonia should form with them triple compounds, than if they contained merely 1 atom. For this reason I have thought proper to keep the atomic number as 80; of

course, whichever number be adopted, it does not affect the statements with respect to the proportions of the ingredients of the compounds by weight.

LEAD.

Lead has been long known. It is of a pale bluish colour when recently cut, but very soon tarnishes by exposure to air. It emits a peculiar odour when rubbed, and leaves a dark stain on paper. It is one of the softest and least malleable of the metals, and is far inferior in malleability, ductility, and tenacity, to iron and copper; a wire of the 1-10th part of an inch in thickness, will sustain a weight of 18 pounds. Its sp. gr. is 1135. Its atomic weight 130.

When subjected to a temperature of about 612, it fuses; and if the heat be raised much higher, it is sublimed.

Oxids.

It is one of those metals which are easily oxidated by heat and air. When kept at a high temperature, it loses its lustre, and acquires a crust on its surface, and at last a white powder is formed. By removing this, or by stirring, the whole is converted to a greenish substance, which is a mixture of oxid with minute particles of metal. By subjecting it to heat and air, a yellow powder is formed, which is a pure oxid, and sold under the name of *massicot*. When this, ground to powder, is kept at a strong heat, the flame of the coals at the same time playing on it, it becomes red, forming *minium*, or *red lead*, and which, when heated suddenly, and a current of air allowed to pass along it, undergoes a sort of fusion, and forms *litharge*.

Massicot, or yellow oxid of lead, is tasteless, and insoluble in water. When heated in close vessels, it forms a transparent yellow-coloured glass; but if air be admitted, it becomes red. A purer yellow oxid may be obtained, by dissolving lead in nitric acid, precipitating by an alkali, and heating the precipitate. This oxid is, according to Berzelius, composed of

lead,	100	or	1 atom,	130
oxigen,	7.7		1 atom,	10
				140

Minium, or red lead, has also been analyzed by Berzelius, who found it composed of yellow oxid, muriate of lead, sulphate of lead, and silica, so that it is not pure oxid; hence, when acted on by acids, it in general gives proto-salts, but not pure. It is supposed, however, by Berzelius and Thomson, that after the impurities are removed, there remains a compound having half again as much oxigen as exists in the protoxid; indeed, from their experiments, it appears to consist of

lead,	100
oxigen,	11.5

Two views may be entertained with respect to its nature. It may be a compound of protoxid and peroxid, in certain proportions, or may contain 2 atoms of copper and 1 of oxigen, and may be therefore called either *deutoxid*, or, as has been done with the oxid of a copper, a *suboxid*. When minium is acted on by nitric acid, it is decomposed, proto-nitrate is obtained in solution, and peroxid is precipitated. We may here explain the action, by supposing that the acid has merely dissolved the one, and left the other, or that it has caused a decomposition; supposing it a suboxid, one part having taken oxigen from the other, the latter to become protoxid, the former peroxid.

Peroxid of lead is of a brownish colour; it is insoluble in water. When exposed to heat, oxigen is given off, and it becomes protoxid. It is composed of

lead,	100	1 atom	130
oxigen,	15.3	2 atoms	20
			150

Oxids of lead are not reduced by heat alone, they require the presence of inflammable matter. Hence, when heated with charcoal, carbonic acid and metallic lead

are formed, or when hydrogen is passed over them at a red heat, water comes off, and lead is left in the tube.

Water, when pure, has no action with lead, provided air is excluded; but if it be admitted, the metal is slowly oxidated and dissolved. This action goes on more quickly when spring water is employed, the presence of the minute quantity of saline matter in it favouring the action. Hence the corrosion of leaden cisterns and pipes conveying water.

The only action of any interest between lead and simple acidifiable bodies, is with sulphur.

Sulphuret.

Lead unites easily with sulphur, the union being effected merely by heating 1 of sulphur with 6 of lead, excluded from air. A dark-coloured substance is formed, which is brittle, less fusible than the metal, and when exposed to a strong heat in close vessels, gives off the whole of its sulphur; but when heated in air, sulphurous acid and oxid of lead are the products. This substance is the same as the native sulphuret called *galena*, and which is a very abundant production, occurring massive and crystallized. It has been analyzed by Berzelius, and found to contain

lead,	100	1 atom	130
sulphur,	15	1 atom	20
			150

This sulphuret, like others, when acted on by diluted acids, gives off sulphuretted hydrogen gas.

The acids in general act on lead with great ease, and form salts containing chiefly the protoxid. They have a sweetish taste, and are decomposed by heat. The first of any consequence is the

Carbonate.

Carbonic acid does not act on lead, but it may be made to unite with its oxid by double decomposition, as

by adding alkaline carbonate to solution of any salt of lead, by which a white precipitate is formed. Though carbonate of lead can be thus procured, it is not prepared in this way. It is much used in commerce, under the names of *white lead* and *cerusse*, employed by painters in making oil-paints. White lead is prepared by first casting the metal into thin sheets, which are coiled up, and put into vessels similar to flower-pots. Into these vinegar is poured, till it reaches near the lower part of the metal; and by the continued application of heat, it is converted to vapour, and, acting on the metal, forms a white crust, which is removed by passing the plates between rollers, or moving them backwards and forwards in water, to prevent the dust from rising, and proving injurious to the workmen. The white lead thus prepared is subjected to the action of water, by which the finer is separated from the coarser part. In this process, the vinegar, a compound of carbon, oxigen, and hydrogen, is decomposed; it gives oxigen to the lead, to convert it to an oxid, while a part of the carbon and oxigen unite, to form carbonic acid, which combines with the oxid, thus producing the carbonate, or white lead.

When carbonate of lead is exposed to heat with charcoal, the acid is expelled, and the metal left pure. It is decomposed by the acids which unite with its oxid, and disengage its acid.

According to Berzelius, it is composed of

acid,	16.5	1 atom	27.5
oxid,	83.5	1 atom	140
			167.5

When a salt of lead is dissolved in common water, the solution is always turbid; or if a transparent solution of any of its salts be diluted with water, it also becomes turbid, from the deposition of carbonate, owing to the presence of some carbonate in the water. The transparency can, however, be easily restored by the addition of a few drops of the acid that exists in the salt employed.

Sulphate.

Sulphuric acid, at a natural temperature, does not act on lead, but when boiled on it the metal is slowly oxidated, at the expense of part of the acid, and sulphate is formed. Sulphate may also be procured by the addition of sulphuric acid or a sulphate to a salt of lead, by which a white powder is deposited.

It may be exposed to a high temperature, without undergoing any change. But when heated with charcoal, it is decomposed, the acid and oxigen being expelled, and the lead left pure. It is soluble in sulphuric acid, forming super-sulphate, in which state it exists in common oil of vitriol, owing to the action of the acid on the lead of the chambers in which it is prepared; and that it does so, is proved by mixing it with water, and allowing the mixture to become cold, by which a white powder is deposited; and hence the method of purifying the acid when required for particular experiments, by diluting it with water, drawing off the clear fluid, and if required strong, concentrating by evaporation.

Sulphate of lead is composed of

acid,	26.5	1 atom	50
oxid,	73.3	1 atom	140
			190

Sulphuretted hydrogen, either gaseous or liquid, throws down a dark-coloured precipitate from any of the salts of lead; and the same happens on the addition of any hydro-sulphuret. It must be considered a sulphuret, the hydrogen of the acid and oxigen of the oxid having combined to form water. It is from the ease with which salts of lead act on sulphuretted hydrogen, that they are employed as tests of it when in solution, *(See Mineral Waters;)* and hence also their use as a sympathetic ink.

There are two kinds of sympathetic ink:—those which are colourless, but may by certain means be made visible; and those which, being coloured, can be made to change their appearance. Salts of lead belong to the first class. If, for instance, traces be drawn on paper with a solution

of any salt of lead, they are invisible, but the moment the paper is immersed in sulphurous water, or after being breathed on to moisten it, is exposed to sulphuretted hydrogen gas, they become black from the deposition of sulphuret. For these experiments, sugar of lead which contains the oxid in union with acetic acid, or acid of vinegar, answers well.

Muriate.

Muriatic acid acts feebly on lead; it dissolves the oxid, and from the solution slender crystals may be obtained. Muriate, (or rather chlorid,) may also be procured by the addition of a concentrated solution of muriate of soda, to that of a salt of lead. It then forms a white powder, soluble in about 22 of cold water. It is soluble in acids, but decomposed by alkalies, its acid seemingly being divided between the alkali and oxid, and forming compounds which may be separated by water, the former only being soluble. The latter is a white powder, but when heated becomes of fine yellow. It is the same as the substance at one time much used as a pigment, under the name of *Turner's yellow*, the residue of a process formerly carried on for decomposing sea salt, but now given up as too expensive.

When sea salt is made into a paste with litharge, it is decomposed, its acid unites with the oxid, and the soda is set free. Hence the patent process of Turner for decomposing sea salt, which consists in mixing two parts of the former with one of the latter, moistening them, and leaving them together for about 24 hours. The product is then washed with water, filtered, and evaporated, by which soda is obtained. A white substance is left undissolved; it is a compound of muriatic acid and lead, and which, when heated, changes its colour, forming Turner's yellow.

The alkalies do not act on lead. They dissolve the oxid, and hence a means of separating them from some of those of other metals.

The oxids of lead form excellent fluxes with earthy

matter; hence they are used for causing them to melt more easily. Thus, litharge is employed in the manufacture of glass, by which the materials are more readily fused, and the glass acquires a greater lustre. (See vol. i. p. 505.) When the litharge is in large quantity, it makes it yellow. White lead is employed, when mixed with powdered flints, and sometimes also with sea salt, as a glazing for stone-ware. (See vol. i. p. 509.)

Lead, in its metallic state, is employed in thin sheets for covering the tops of houses, and in finer plates for lining the inside of boxes, and for covering the mouths of bottles in which volatile fluids are kept, the bottle being first covered with bladder, then with sheet lead, and again with bladder.

Lead is an abundant production of nature. The ore from which it is usually procured, is the *sulphuret*, or *galena*, and which is easily reduced by heat alone. For this purpose, after being freed from its stony impurities, it is placed in a furnace, and made quickly red hot, being frequently stirred; and when it begins to soften, the temperature is reduced, till the whole of the sulphur is expelled. The fire is then made brisk, to cause the lead to be melted, and collect at the bottom of the furnace; after which, lime is thrown in, to thicken the impurities that collect on the surface, and the fused metal is drawn off into oblong moulds.

Lead ore frequently contains a sufficient quantity of silver to make it of consequence to extract it from it. *(See Silver.)*

TIN.

Tin has been long known. It is of a whitish colour, with considerable lustre, having somewhat the appearance of silver. It is very malleable, being easily beat out to leaves which are generally about 1-1000th part of an inch in thickness, but finer leaf can also be prepared. It is not

possessed of much ductility, nor is it very tenacious, a wire of the 10th part of an inch sustaining a weight of only about 50 pounds. It has but little elasticity, and in bending emits a crackling noise. It is so soft, as to be easily cut. When exposed to air, it tarnishes, though slowly. It melts at 442, and if the heat be continued, it acquires a white crust on its surface, which soon becomes yellow; and if the temperature be high, and a stream of air passed over it, it takes fire and forms an oxid, as is easily shewn, by melting it in a ladle, and blowing on it, taking care to keep up the heat. Its sp. gr. is 7200. Its atomic weight 72.5.

Oxids.

Tin forms with oxigen two oxids:—the protoxid, or that generated by exposing it to a moderate heat; and the peroxid, or that obtained by subjecting the former to a higher temperature.

Protoxid, though it may be formed by the exposure of tin to heat, is obtained in a greater state of purity by other processes. By dissolving the metal in muriatic acid, excluded from air, precipitating by potass, and drying the precipitate, or by pouring very much diluted nitric acid (1 to 10,) on tin, and allowing the action to go on spontaneously, a protoxid is formed. It is of a dark grey colour; is insoluble, and not decomposed by heat. According to Dr Davy, Berzelius, and others, it is composed of

tin,	100	1 atom	= 72.5
oxigen,	13.6	1 atom	= 10
			82.5

Pure peroxid may be obtained by exposing the protoxid to heat and air, or by throwing tinfoil into nitric acid, diluted with an equal quantity of water. Nitric oxid is given off, and a white powder is left, which, after being washed and slightly heated, to carry off superfluous acid, is peroxid. It is decomposed by heat. It

is insoluble in acids unless when in the state of hydrate. It is composed of

tin,	100	1 atom	= 72.5
oxigen,	27.2	2 atoms	= 20.

Another oxid has been mentioned by Berzelius, in which the oxigen is in quantity intermediate to that in the other oxids, but its existence has not been sufficiently established by experiment.

In throwing down the oxids of tin from any of their salts, they are generally in the state of *hydrate*, but from which the water is expelled by heat.

Sulphuret.

Tin unites with sulphur, and forms two compounds, a proto-sulphuret, and per-sulphuret. When tin, sulphur, muriate of mercury, and muriate of ammonia, are heated together, a substance of a golden colour is formed, long known by the name of *aurum musivum*. This is now generally procured by heating equal parts of sulphur and the protoxid, by which sulphurous acid is disengaged, and sulphuret of tin is left. When first prepared, it was supposed to be sulphuret of the oxid, but the experiments of Davy and Berzelius have proved it to be a sulphuret of the metal. It is obtained in small shining scales of a golden yellow colour. When exposed to a strong heat, excluded from air, sulphur is expelled, and another sulphuret, with a less proportion of sulphur, is formed.

The latter of these is *proto-sulphuret*, composed of

tin,	100	1 atom	= 72.5
sulphur,	28	1 atom	= 20;

and the former is a per-sulphate, composed, according to Davy, of

tin,	100	1 atom	= 72.5
sulphur,	56.25	2 atoms	= 40.

Proto-sulphuret of tin may also be obtained by heating together tin filings and sulphur, and continuing the heat till the excess of the latter is expelled.

The acids act easily on tin, and form salts containing both of the oxids.

Nitrate.

When tinfoil is thrown into nitrous acid, previously mixed with a little water, a white powder is deposited; hence, if we wish the metal to be dissolved, and a salt to be formed, the acid must be more diluted. If it be largely diluted, the action goes on very gradually, the metal acquiring oxigen both from it and the water; and as nitrogen from the one, and hydrogen from the other, come off, they unite, and form ammonia, so that the fluid contains nitrate of tin, and nitrate of ammonia; and that it does so, is proved by the addition of lime, by which the alkali is disengaged. This formation of ammonia is generally given as one of the synthetic proofs of its composition.

When sulphuretted hydrogen gas is passed through a solution of a salt of tin, containing the protoxid, a dark-coloured precipitate is formed; but when one with the peroxid is used, the precipitate is of the colour of the *aurum musivum.*

Muriate.

By far the most important salt of tin, is that with muriatic acid. This acid acts feebly on it, at a natural temperature; but by the application of a slight heat, it dissolves it, the metal having previously acquired oxigen from the water. The muriate thus formed, is of a pale yellowish colour, easily decomposed by the affusion of water, a whitish powder being precipitated.

Muriate of tin has a great tendency to absorb oxigen; hence, when exposed to the air, it unites with it, and becomes *permuriate.* If, when in this state, it be concentrated by evaporation, a fuming fluid is obtained, formerly known by the name of *fuming liquor of Libavius*, owing to the emission of white fumes, which are the salt itself rising in vapour, and uniting with the moisture of the air. This, according to some, is not a muriate, but a liquid chlorid, containing only chlorine and tin, the whole of the hydrogen of the acid, and oxigen of the oxid, having been expelled by evaporation.

A similar compound may be obtained by distilling 1 of powdered tin with 3 of corrosive sublimate, (perchlorid of mercury,) by which the chlorine is transferred to the tin, and chlorid is sublimed, and may be condensed in the receiver. When thus procured, it emits fumes the moment it is exposed to the air. According to Dr Davy, it consists of tin 58, chlorine 72, which is very nearly 1 atom of the former to 2 of the latter; so that it may be considered a *per-chlorid*, analogous, of course, to the solution of per-muriate.

From the great avidity of proto-muriate of tin for oxigen, it absorbs it from many of the per-salts of other metals, and reduces them to the state of proto-salts.

The action of nitro-muriatic acid on tin, is also important. When pieces of tinfoil are thrown into it, a transparent brownish fluid is formed, which becomes of the consistence of jelly, and is decomposed by the addition of water, the oxid being precipitated.

Muriates of tin are employed by dyers as mordants, and also for affording a rich red colour with some dyestuffs. A cheap solution of tin for the same purpose, is prepared by dissolving 14 ounces of it in 3 pounds of muriatic and 1 of sulphuric acid. *(Bancroft on Dyeing.)* The colour, with per-muriate, is not only bright, but permanent; and hence its use in making *red ink*. To make this, boil 1 lb. of chips of Brazil logwood in three quarts of water, for half an hour; strain the decoction, and evaporate to a pint (English,) then add half an ounce of solution of muriate of tin which has been exposed to the air, half an ounce of spirit of wine, a quarter of an ounce of muriatic acid, and a quarter of an ounce of brown sugar. Muriate of tin, for this purpose, is prepared, by dissolving tinfoil in muriatic acid, keeping the flask near a fire to promote the action.

The alkalies unite with the oxids of tin, and likewise with some of its salts, forming triple compounds. The earths also combine with the oxids, and form an opake glass; and hence its use in the manufacture of enamel.

Alloys.

Tin unites with the greater number of metals, with some of which it forms very important alloys. It does not combine very easily with iron, but they can be made to enter into union, by melting them in a covered crucible. Tinning of iron depends on the attraction exerted between them. *Tinned iron*, or *white iron*, as it is commonly called, and sometimes, but improperly, tin, is formed, by dipping very thin sheets of iron into melted tin, previously mixed with about 1-10th part of copper, which prevents too much of it from adhering to the iron, and having its surface covered with tallow, to keep it from undergoing oxidation, at the high temperature to which it is exposed.

Tinned iron is a very useful alloy; it does not easily rust; besides, the elasticity of the iron is not much impaired, and, owing to the fusibility of the tin on its surface, two pieces of it are easily soldered together.

Pots are often lined with a thin layer of tin, which is done by first rubbing over their surfaces with sal ammoniac, and after heating them, pouring in some melted tin, and revolving them, so that the whole of it may be brought in contact with the iron, by which it acquires a coating, that prevents it from undergoing any change by exposure to air.

Perhaps the alloys of tin and copper are the most useful. Tin diminishes the ductility, but increases the hardness and tenacity of copper, and it also renders it more sonorous, and more easily fused. To procure an alloy in the proportion in which the metals are mixed, it is necessary to keep the mixture long in fusion, and to stir it constantly during cooling. In this way are formed *bronze*, *gun metal*, *bell metal*, and that used for the reflecting mirrors of telescopes. The two first are compounds of 100 copper, and from 8 to 10 of tin. The alloy is yellow, and is more easily melted than copper; hence its use in making statues. It was used also by the ancients before iron was known, for swords, spears, and

other warlike instruments, and many of their sharp-edged tools and medals were made of it. Bell metal is composed of 100 of copper, and about 30 of tin, the conch of the Indians being nearly of the same composition; and the metal for telescopes contains a still larger proportion of tin, about 100 to 50.

Tin unites with lead in almost every proportion; the alloy is easily fused, hence it is employed as a solder; plumbers' solder being usually composed of about equal parts of tin and lead.

Tin is not an abundant production of nature. It is found in but few places, as in Gallicia in Spain, in Saxony, Bohemia, and in Cornwall in England. Its ores are the sulphuret and oxid, from the latter of which it is got, by heating it with inflammable matter. For this purpose, after being freed as much as possible from earthy impurities, it is roasted to drive off any sulphur, and then mixed with coal or coke, and again subjected to heat, during which the carbon unites with the oxigen, and the tin, brought to its metallic state, is fused, and is drawn off in shallow pits. When solid, it is exposed to a moderate heat, so as to melt the purest part, which is run off into moulds, and forms *grain tin.* What is left is common tin, which is not so pure as the other, containing a little copper, iron, and arsenic.

ZINC.

Zinc has not been long known, but one of its compounds was used by the ancients in the formation of brass, of the nature of which, however, they were ignorant. The metal itself seems to have been discovered about the middle of the 16th century.

When pure, it is of a bluish colour, hard and brittle, and, when recently broken, of considerable lustre. Its sp. gr. varies from 6870 to 7100, the lightest being considered the purest. Its atomic weight is 42.5. It was formerly considered one of those metals not possess-

ed of malleability or ductility, but is now known to have both of these qualities. By cautious and equal pressure, it may be extended to plates, and by heating it to a certain temperature, its malleability and ductility are much increased. The degree at which this takes place, is from 212 to 300. It may be then beat to thin plates, and drawn into fine wire, which, when annealed, retains considerable tenacity, one of the 10th of an inch in thickness sustaining a weight of about 26 lb.

If the zinc be raised much beyond the temperature stated, as to about 400, it becomes so brittle, that it is easily reduced to powder.

When heated in close vessels to about 680, or 700, it melts, and by a higher temperature is volatilized.

When exposed to the atmosphere, it is slowly tarnished; but does not undergo any particular change.

When heated in contact with air, it soon acquires a crust on its surface, and if it be stirred when in this state, the whole of it is converted to a greyish powder, which is an oxid. If the temperature be high, it takes fire and burns with a bright flame, which becomes more brilliant by blowing on it, (vol. i. p. 192.)

Oxid.

The oxid thus formed is grey, and cannot be decomposed by heat alone; it requires the presence of inflammable matter, as charcoal; and the process must be carried on in vessels from which the air is excluded, otherwise the metal, when formed, instantly unites with oxigen, and again becomes an oxid.

Oxid of zinc is sometimes employed by painters, instead of white lead, in the preparation of their paint. Though it is more troublesome to work with, yet in other respects it is preferable to white lead. It is not at all liable to become dark coloured, and it does not prove injurious to the workmen.

We are acquainted with only one compound of zinc and oxigen. It is that formed by the action of heat and

air on the metal, or it may be prepared by precipitation from any of its salts. It has been examined by Proust and Berzelius, who agree in making its composition to be,

zinc,	100	1 atom,	42.5
oxigen,	24.5	1 atom,	10
so that its atomic weight is			52.5

Zinc decomposes water at a natural temperature, slowly acquiring a crust on its surface, and at the same time evolving hydrogen gas. If the water be brought into contact with it at a high temperature, the decomposition is rapid, and accompanied with the evolution of a large quantity of hydrogen, and the formation of the oxid already described.

Sulphuret.

The only action of any interest between zinc and simple acidifiable bodies, is with sulphur. The compound is not easily formed synthetically, the substances having apparently little affinity for each other. When, however, sulphur and the oxid are heated, oxigen is disengaged, and a sulphuret is formed. The same is produced by passing a stream of sulphuretted hydrogen through solution of a salt of zinc, or by subjecting dried sulphate to heat along with charcoal, by which the oxigen of the acid and oxid combine with the carbon, and leave the sulphur and metal in union. The sulphuret is white, in this respect differing from those of other metals. It resembles in its composition the native compound called *blende*, and which, according to Thomson, contains

zinc,	67.2	1 atom	42.5
sulphur,	32.8	1 atom	20

Nitrate.

The acids act with great ease on zinc, owing to its powerful attraction for oxigen. When zinc filings are thrown into nitric acid, diluted with an equal quantity of water, the action is violent, and accompanied with the disengagement of nitric oxid; it is necessary therefore to have the acid more diluted, to allow the solution to go

on slowly. The product is a transparent colourless fluid, which on evaporation yields crystals of nitrate.

Carbonate.

When to a solution of nitrate, or of any other soluble salt, that of an alkaline carbonate is added, a white carbonate of zinc is precipitated. The carbonate is, however, seldom prepared in this way, being a native production, known by the name of *calamine*, and of which there are two kinds; the *hydrous* and *anhydrous*, the latter, according to Thomson, composed of

acid,	34.37	1 atom	27.5
oxid,	65.63	1 atom	52.5

and the artificial compound prepared by precipitation and cautious drying, is of the same composition.

Hydrous carbonate is of a yellowish white colour, and is generally stalactitical. It is, according to the same authority, composed of

1 atom acid,	27.5
1 atom oxid,	52.5
1 atom water,	11.25

Sulphate.

By far the most interesting action of zinc and acids, is with sulphuric. Concentrated oil of vitriol does not act on zinc, but when water is added, there is an immediate action and disengagement of hydrogen gas, so that the metal must acquire oxigen, not from the acid, but from the water. The hydrogen given off in this process, is much purer than that got by the action of iron. It is of less specific gravity, and has also a less unpleasant odour. Hence the method generally practised when it is required pure. For this purpose, 4 parts of zinc, and 5 of sulphuric acid, are put into a retort, along with 20 of water, and the action allowed to go on for a short time before the gas is collected. When it has ceased, there remains in the retort a small quantity of carbonaceous matter, derived from the impurities of the zinc. The solution is transparent and colourless, and yields on evaporation,

beautiful transparent right rhombic prisms of sulphate of zinc, or *white vitriol* of commerce. The composition of the sulphate varies, at least with respect to the quantity of water of crystallization, according to the mode of preparation. When obtained by the spontaneous evaporation of a cold solution, they contain

acid,	27.58	1 atom	50
oxid,	28.96	1 atom	52.5
water,	43.46	7 atoms	78.75

When procured by cooling a warm saturated solution, they contain

acid,	36.7	1 atom	50
oxid,	38.54	1 atom	52.5
water,	24.76	3 atoms	33.75

Sulphate of zinc has a disagreeable styptic taste. It is soluble in 1.4 of water at 60, and at a boiling heat, in its own water of crystallization. When the temperature is raised, the whole of the water is expelled, and the dry salt left, which, by the application of a still stronger heat, is decomposed, the acid being expelled, and leaving the oxid pure. It is decomposed by the alkalies, and by the alkaline carbonates, the oxid being precipitated by the former, and carbonate by the latter.

Though sulphate of zinc can be prepared by the solution of the metal in diluted sulphuric acid, it is seldom obtained from that source, being in general procured by a process similar to that by which sulphate of iron is formed, by roasting the native sulphuret, by which the sulphur and metal both acquire oxigen, and become sulphate. The residue is then dissolved, filtered, and evaporated, and yields white vitriol of commerce. This is not, however, a pure sulphate. It contains a little iron, which gives it a brownish tinge, and when dissolved in water, affords a solution apt to throw down a brownish precipitate, when kept for some time. Hence, when employed in medicine, either as an emetic or as a wash, it is ordered to be prepared by the solution of the metal. The process is the same as that followed in the preparation of hydrogen gas.

It has been already mentioned, that when sulphuretted hydrogen is added to a salt of zinc, a white precipitate is formed, and which is a sulphuret. This is also easily procured, by the addition of an alkaline hydrosulphuret to the sulphate. The action of sulphuretted hydrogen is quite characteristic of zinc, and sufficient to distinguish it from other metals.

Ferro-cyanate.

On the addition of ferro-cyanate of potass to solution of sulphate of zinc, a white precipitate falls, which is ferro-cyanate of zinc. The white vitriol of commerce, however, affords a pale blue one, owing to the presence of iron.

The alkalies unite with the oxid of zinc, and form a compound soluble in water. On the addition of potassa to the solution of the sulphate, a white oxid is deposited, but disappears on adding an excess. From the solution the oxid may again be precipitated, by the neutralization of the alkali.

Alloys.

Zinc unites with a number of the metals, and forms some very important alloys, the most useful of which is *brass.*

Owing to the low temperature at which zinc is melted, and even volatilized, it is difficult to obtain a perfect alloy of it and copper, because, before the latter is fused, a great deal of the former is dissipated. There is, however, an easy method of alloying them by what is called *cementation*, which consists in exposing copper to heat, along with a mixture of zinc ore and charcoal, during which the ore is decomposed, zinc is formed, and unites with the other, and converts it to brass. For this purpose, the ore, after being roasted, is mixed with charcoal, and put into large earthen pots with pieces of copper, and when the lids are secured, heat is applied, sufficient to soften, but not to melt the copper, because the zinc, when brought to its metallic state, will penetrate it; but

after the brass is formed, the temperature is raised, by which it is melted and drawn off into moulds. The proportions of the ingredients of brass vary in different places. In some, 40 of copper and 60 of zinc ore are employed, which yield about 60 of alloy, making the proportions 2 of the former to 1 of the latter. It is seldom, however, that the quantity of zinc is so high; in general it does not exceed 20 per cent.

Brass is more fusible than copper, and is malleable when cold. It possesses, however, one disadvantage, that of being decomposed at a high temperature, for, when kept long melted in contact with air, the greater part of the zinc is consumed; so that, in working with it, the temperature ought not to be allowed to approach that at which the zinc will be taken from it.

Zinc with a larger proportion of copper forms alloys, which are only employed in making trinkets, as *pinchbeck*, *tinsel*, and *Dutch-leaf*. These are generally procured by melting brass with an additional quantity of copper, the proportions varying according to the colour required.

Zinc, by its strong attraction for oxigen, decomposes the salts of other metals, with the oxigen and acid of which it unites to form a soluble compound, while the other metal is deposited in its metallic state. The action is well illustrated with salts of lead; and, when a weak solution is used, it goes on slowly, and the metal, during its decomposition, assumes a *dendritic* appearance. Hence the method of forming what is commonly called a *zinc tree*, but, properly speaking, a *lead* tree. For this purpose, a piece of rough zinc is suspended near the top of a tall bottle, full of a solution of a salt of lead, and kept without agitation. The moment it is introduced, it is covered with a thin film of lead, the quantity of which gradually increases, till at last it nearly occupies the whole of the bottle. The salt employed, is sugar of lead, one ounce of which is dissolved in 30 of water, and the solution filtered; or, to render it clear, a few drops of vinegar may be added.

In this instance, the decomposition is generally ascrib-

ed to the superior affinity of the zinc for oxigen, but it is evident from the manner in which the lead is deposited, that, besides this, there is an action of a different nature. It is supposed that galvanism is concerned in causing the dendritic appearance. When the zinc is put into the solution, owing to the strong affinity for oxigen, it takes it from the oxid of lead, itself becomes oxid, and unites with the acetic acid, forming an acetate, which is dissolved; while the lead, deprived of its oxigen, is deposited in its metallic state, and adheres to the zinc. There are therefore two metals in contact in a saline solution, by which galvanism is excited, and causes the decomposition of the water; its hydrogen being evolved where it is in contact with the lead, and its oxigen where it is in contact with the zinc. The zinc and oxigen unite, and form oxid, while the hydrogen is supposed to deprive the oxid of lead of its oxigen, generate water, and cause the deposition of lead. If this explanation be adopted, we can easily conceive why the lead should be deposited at a distance from the apparent sphere of action, and thus assume the dendritic form; in fact, the deposition of lead is going on, not where the zinc is in contact with the solution, but at the extremities of the tree, each particle set free attaching itself to that deposited immediately before it.

Zinc does not occur in its metallic state, nor are its ores numerous. It is found chiefly in union with sulphur and carbonic acid, in the substances called *blende* and *calamine*, from which it is always obtained. For this purpose, the ore is first roasted, to drive off the carbonic acid from the one, and the sulphur from the other; after which it is mixed with charcoal, and *reduced* by the application of heat. The vessels in which the smelting is conducted, are large earthen pots, through the bottom of which there passes a tube, the upper end terminating by an opening near the top; the lower one going through the furnace into water. After they are filled with the mixture of ore and charcoal, the lids are put on, and heat applied, by which the metal is reduced and con-

verted into vapour, which passes through the tube, and is condensed in the water. It is after this melted, and poured into moulds.

MERCURY.

Mercury, or *quicksilver*, was well known to the ancients, and used by them in many of their operations. It is distinguished from other metals by its being fluid at a natural temperature. It has a bluish white colour, and very resplendent. Its sp. gr. is 1356. Its atomic weight 250. When thrown on a table, it collects into a globule, and provided it is pure, runs without leaving a tail. It has neither taste nor smell. By exposure to air, it attracts moisture and dust, which render its surface dull; but it is easily freed from these by squeezing it through a leather bag.

By the abstraction of caloric mercury may be made to freeze, the congelation occurring at about —39, and during its change of form, contracts considerably, consequently increases in specific gravity. It was this that gave rise to the idea, that the freezing point was very low. In Braun's experiments the thermometer was found to stand at —556, and which was occasioned by the mercury having been frozen, and during its congelation and contraction sunk in the stem of the instrument. According to Cavendish, the diminution is equal to what it would suffer by passing from 500 to 0, that, is about 1-23d of its volume.

Solid mercury, according to Biddle, is of sp. gr. 1561. It is malleable, and easily cut, presenting the appearance of a piece of recently cut lead.

Mercury at a natural temperature is, according to Faraday, constantly giving off a little vapour. If, for instance, a piece of gold leaf be suspended at the top of a phial in which there is a little mercury, it becomes slowly amalgamated, proving that part of the fluid must have risen in vapour to affect it.

By the application of heat, mercury expands more uniformly than any other fluid; indeed, according to Dulong and Petit, the expansion between 32 and 212 keeps pace with the increase of temperature; and hence its value in the construction of thermometers.

The boiling point of mercury has been differently stated. It is according to Irvine 672,—Creighton 655,—Dalton 666,—Daniells 644. It then passes off in vapour, which condenses unchanged in its properties, in the cool part of the apparatus. By this means, we are enabled to free it from the impurities which it usually contains, as when it is required pure for filling thermometers. For this purpose, it is placed into an earthenware or iron retort, the mouth of which terminates in a basin of water. By applying heat, the mercurial vapour is given off, and condensed in the water, from which it is easily freed, by pouring off the fluid, and then passing the mercury through a towel, and keeping it in bottles, so as to exclude it from the air.

Mercury is not acted on by water.

Oxids.

Mercury is not oxidated by mere exposure to air, but it may be converted to an oxid by agitation or trituration in contact with it even at a natural temperature. When, for instance, a phial with a little of it is tied to the wheel of a carriage, or to any piece of machinery, a greyish-coloured powder is gradually formed, more particularly if moisture is also present. When it is triturated with any viscous or unctuous substance, the oxidation is hastened; and hence the method of oxidating it, as ordered by the pharmacopœia in the preparation of blue ointment and blue pill, in which it is rubbed along with lard or conserve of roses.

The oxid prepared in this way is, however, seldom pure. It contains a great deal of metallic mercury; and hence the difference in the statements given with respect to its composition. When properly formed, it is a dark-coloured powder, insoluble in water, and easily decom-

posed by heat. The statements given of its composition all very nearly agree. They are, according to

	Davy.	Fourcroy.	Donovan.
metal	100	100	100
oxigen	3.94	4.00	4.12.

That of Fourcroy may be considered correct, for

as 100 : 4 : : 250 : 10 ;

so that it is a *protoxid*, composed of

1 atom mercury, -	250
1 atom oxigen, -	10
its atomic weight being	260

Protoxid of mercury may also be prepared by the action of solution of potass or lime on the proto-chlorid, by which the hydrogen unites with the chlorine to form muriatic acid, and the oxigen with the mercury to form protoxid. Hence the method given in the pharmacopœias for procuring it. *(See Calomel.)*

When the protoxid is exposed to heat and air, it absorbs more oxigen, and becomes *peroxid*; and the same happens also with metallic mercury, the oxigen being slowly absorbed. The best apparatus for this purpose is a flask, with a flat bottom, and long narrow neck, so that the air may be freely admitted, but the vapour of the metal prevented from escaping. By long continued heat in this way, a reddish-coloured substance is formed. The process is, however, a very tedious one, requiring the action to be kept up for weeks.

The oxid thus prepared is easily decomposed by a strong heat, the whole of the oxigen being expelled, and the metal left pure. It contains double the quantity of oxigen that exists in the protoxid. It is therefore composed of

metal,	100	1 atom,	250
oxigen,	8	2 atoms,	20
		and its atom,	270

Red oxid is more easily procured by the decomposition of the nitrate, by a process which will be immediately

described. As thus obtained, it is in shining scales, having an acrid taste, and very corrosive, and hence its use as an escharotic, being much employed as a stimulant application to ulcers.

From the ease with which it parts with its oxigen, it is employed for yielding it, when required pure for particular purposes. All that is necessary is to put it into a small retort, and apply heat.

The action between mercury and some of the simple acidifiable bodies is interesting, particularly with sulphur and chlorine.

Sulphurets.

Mercury unites with sulphur by synthesis. When equal weights of them are rubbed together in a mortar, the metal soon disappears, and a black powder is gradually formed, which, when properly prepared, is a *proto-sulphuret*. This may also be obtained by fusing sulphur with mercury, or by the addition of a hydro-sulphuret to a mercurial proto-salt, by which a black precipitate is formed. This sulphuret is the same as the substance long known by the name of *Ethiops Mineral*. It is, according to Guibourt, composed of

metal,	100	1 atom	=	250
sulphur,	8.2	1 atom	=	20

When exposed to heat it is decomposed, and metallic mercury is sublimed, along with a dark-coloured substance, but which, when reduced to powder, becomes bright red. This is also a sulphuret, containing more sulphur than the preceding; it is evident, then, that one part must have taken sulphur from the other to form it. According to Guibourt, it contains

metal,	100	1 atom,	=	250
sulphur,	16	2 atoms,	=	40

so that it is a *bi-sulphuret*.

When the bi-sulphuret is reduced to very fine powder, by long trituration with water, it assumes a beautiful red colour, and is then known by the name of *vermilion*.

By exposure to a red heat, along with iron filings, it is

decomposed, the iron unites with its sulphur, and the mercury is set free, and distilled over; and hence the method of procuring it by the decomposition of the native sulphuret called *cinnabar*.

Chlorurets.

When mercury is heated in chlorine gas it is inflamed, and a whitish crystalline-looking substance is formed, composed, according to Thomson, of

metal,	100
chlorine,	34.6

and as 100 : 34.6 : : 250 : 90;

so that it is a *bi-chlorid*.

When thrown into water it is converted to *per-muriate*. Though bi-chlorid can be procured by the action of chlorine on mercury, it is never prepared in this way for use. It is obtained by the decomposition of the sulphate, by a process of sublimation; and hence its name, *corrosive sublimate*. *(See Muriate.)*

When bi-chlorid is triturated with about an equal quantity of mercury, the latter disappears, and a blackish-looking substance is formed, which, when sublimed, yields *calomel* or *proto-chlorid*. *(See Muriate.)*

Calomel or proto-chlorid, as usually prepared, is in cakes, which, when reduced to powder, become quite white. Its sp. gr. is 7100. It is tasteless, and very sparingly soluble, requiring, according to Rouelle, 1152 of boiling water to dissolve it. By the application of heat it is sublimed and condensed, unchanged in its properties.

It contains exactly half the quantity of chlorine that exists in the other. It is composed therefore of

metal,	100	1 atom,	250
chlorine,	17.3	1 atom,	45

When calomel is exposed to light, it gradually becomes dark-coloured. When kept in chlorine gas, or in its solution, it is slowly converted to per-chlorid.

The alkalies and alkaline earths decompose it, and precipitate a black powder, which is a protoxid, and hence the method ordered by the Pharmacopœia for procuring

it, already alluded to. When, for instance, it is thrown into solution of potass or of lime, the water is decomposed, the oxigen uniting with the mercury, and the hydrogen with the chlorine, so that oxid of mercury is precipitated, and muriate of lime, or of potass, remains in solution. The process given in the Edinburgh Pharmacopœia, consists in agitating together 5 pounds of lime water and half an ounce of calomel, filtering and washing the precipitate. The mixture formed in this case is well known by the name of *black wash*, much used as an application to venereal ulcers. It is of course a solution of muriate of lime, holding black oxid suspended in it, so that, if it acts as a mercurial, it must be by the powder thrown on the sore, the bottle being always shaken before its application.

Calomel is used as a purgative, in the dose of five or six grains, but in general in conjunction with other substances. In smaller doses, along with opium, it is administered as a mercurial when slight salivation is required.

Salts of Mercury.

The acids in general do not act easily with mercury, but they unite with its oxids, and form a very interesting class of salts, which have been examined with great care.

Nitrates.

Nitric acid, when diluted, acts easily on mercury, but the product differs according to the mode in which the action is carried on. When it goes on slowly, and without the aid of heat, the mercury is oxidized to the minimum, and *proto-nitrate* is formed. For procuring this, the metal must be put into its own weight of diluted acid, (equal parts acid and water), and the action allowed to go on spontaneously. Should it not commence, a very slight heat may be applied, but removed the moment it begins. The solution is transparent and colourless, very acrid and caustic, tinging the skin red. By

evaporation and cooling, it affords crystals of proto-nitrate, leaving a solution consisting chiefly of per-nitrate.

When solution of proto-nitrate of mercury is evaporated to dryness, and afterwards exposed to heat, it is decomposed, and a powder is left, which is the peroxid. Hence the method of preparing the *Oxidum Hydrargyri Rubrum Per-Acidum Nitricum* of the Edinburgh Pharmacopœia. For this 3 parts of mercury are dissolved in 4 of diluted nitrous acid, as already described. The solution is evaporated to dryness, the residue ground to powder and placed in a glass dish, with a thick plate of glass resting on it. Heat is applied, and continued till the whole becomes quite red. In the latter part of this process the proto-nitrate is decomposed, its acid being expelled, but at the same time its oxid acquires more oxigen, and is converted to peroxid; so that, when properly prepared, the product is red oxid, but it frequently contains a little nitric acid, probably from the whole of the nitrate not being decomposed. The use of the glass plate is to cause the decomposition to go on slowly, so as to communicate to the powder a shining scaly appearance.

Proto-nitrate of mercury is decomposed by the alkalies and alkaline carbonates. It is also decomposed by muriate of soda, and the action is important, as affording a method of preparing calomel or proto-chlorid by precipitation. Owing to the tedious nature of the process for procuring calomel by sublimation, it was recommended by Scheele to throw it down from the nitrate, and hence that of the Pharmacopœia for procuring *Calomel Precipitatum.*

Proto-nitrate is formed in the usual way, by dissolving mercury in its own weight of diluted nitric acid, digesting towards the end with a very slight heat, and throwing the solution, while warm, into that of half the quantity of seasalt. A white powder falls, which must be well washed with hot water. On mixing the solutions, the nitric acid and soda unite, to form soluble nitrate of soda, while the muriatic acid and oxid acting on each other, undergo decomposition; the hydrogen of the one,

and oxigen of the other, form water, while the mercury and chlorine are precipitated in the form of chlorid.

As in this instance proto-nitrate is used, a proto-chlorid must be precipitated, because the muriatic acid and oxid contain an atom of each of their ingredients, so that the atom of oxigen must take an atom of hydrogen, and set free one of chlorine, to unite with the mercury. In conducting the process, however, it is very difficult to get the solution completely in the state of proto-nitrate, it almost always contains a little per-nitrate, consequently, when added to the sea salt, per-muriate of mercury, or corrosive sublimate, is also formed, and which remains in solution; and hence the reason why the precipitate requires to be so well washed. But in addition to this, per-nitrate of mercury is decomposed by water alone, a yellowish powder being thrown down. If, therefore, the solution contain any per-nitrate, the precipitated oxid is mixed with the calomel, and gives it properties different from those of that prepared by sublimation. When the latter is washed with lime water, it gives a black oxid, as already described, but when the former is treated in the same way, the powder is brownish, owing to the presence of the substance thrown down from the per-nitrate, with which the proto-nitrate was mixed. Hence it has been recommended to submit it to sublimation, to free it from the impurities, and after this to reduce it to powder.

It has been ordered by some to wash the precipitate with sea salt, with the view of removing the impurities; but this is dangerous, because calomel, when treated with warm solution of salt, is changed to per-muriate.

Per-Nitrate.

If, instead of allowing the solution of the metal in nitric acid to go on slowly, it be promoted by the application of heat, the mercury acquires a sufficient quantity of oxigen to form it into peroxid, so that per-nitrate is produced. The properties of per-nitrate are nearly the same as those of proto-nitrate. The solution is trans-

parent and colourless, and on evaporation yields crystals, which, when subjected to heat, give off their acid, and leave pure red oxid, but not having the shining scaly appearance of that prepared from the proto-nitrate.

Solution of per-nitrate is decomposed by water, but the colour of the precipitate depends on the temperature. With cold water it is white with a slight tinge of yellow, but at a boiling heat it is brownish. According to Donovan, (An. of Ph. xiv.) it is a mixture of *sub-proto-nitrate* and *sub-per-nitrate*, in proportions varying according to the temperature. According to Thomson, the precipitate is peroxid, the acid being removed by the water.

The alkalies, and their carbonates and phosphates, throw down precipitates of the oxid, carbonate, and phosphate from the per-nitrate. The alkaline earths also precipitate the oxid.

Sulphate.

The action between mercury and sulphuric acid is interesting, as affording a means of procuring sulphurous acid, and yielding also products, by the decomposition of which several important compounds can be obtained. Sulphuric acid does not act on mercury at a natural temperature, but by the application of heat part of the acid is decomposed, the mercury acquiring oxigen from it, becoming oxid, and uniting with the remainder, while sulphurous acid is disengaged. Hence the method generally followed for procuring the acid gas. For this purpose, equal parts of mercury and acid are put into a retort, and heated, the heat being such as just to keep up the effervescence, because when too high, some of the latter is driven off in vapour. The gas, as it is easily absorbed by water, must be collected over mercury.

When the action has ceased, there remains in the retort a white crystalline mass, consisting partly of proto-sulphate, and partly of per-sulphate. A proto-sulphate may, however, be obtained by heating cautiously the mixture of acid and metal, or by diluting the mixture, so as to make the action go on slowly. The salt is sparing-

ly soluble in water, requiring about 600 of cold and 280 of boiling water for solution.

When 3 of acid are boiled on 2 of metal, the common sulphate is formed, but by the continuance of the heat, the superabundant acid is decomposed, and gives more oxigen to convert the metal into peroxid, and produce a per-sulphate.

As thus procured, it is a white saline mass, not altered by exposure to air, but decomposed by water. When thrown into it, a yellow powder is precipitated, supposed to be a sub-sulphate, and hence the process ordered in the Pharmacopœia, for procuring the *sub-sulphas hydrargyri flavus*, or what is commonly called *turpeth mineral.* In preparing it, the sulphate procured by the process mentioned, is thrown into boiling water, and the yellow powder instantly appears.

According to Donovan, this is a *subsalt*, containing the acid in union with both oxids, but Thomson and Fourcroy state that it is a *neutral per-sulphate*, consisting of an atom of acid and of oxid. They consider the salt formed by the solution of the mercury in the acid, as a *bi-per-sulphate*, and that by the affusion of water, the superabundant atom is removed, and the neutral sulphate, containing an atom of acid and base, is precipitated.

Muriate.

Muriatic acid does not either in the gaseous or liquid form act on mercury. It has been already mentioned, that by the action of chlorine, a chlorid may be formed, which, when thrown into water, becomes per-muriate. The salt is not, however, prepared in that way, it is always procured by the decomposition of the sulphate by sea salt. Hence the process of the Edinburgh Pharmacopœia. For this purpose, 4 of mercury are dissolved by the application of heat, in 5 of sulphuric acid, so as to obtain a per-sulphate, which when dry is mixed with 8 of dried sea salt, and sublimed in the usual way. A crystalline mass is condensed in the cool part of the appara-

tus, which is per-muriate, or, adopting strictly the views of Davy, per-chlorid. In the latter part of the process, in which the salt, (chlorid of sodium,) is heated with the per-sulphate, the oxigen of the oxid of mercury oxidizes the sodium, and the soda thus formed unites with the sulphuric acid. The chlorine and the mercury form a chlorid, which rises in vapour.

It is evident that this substance must be a *bi*-chlorid, even though we are using *proto*-chlorid of sodium, because the two atoms of oxigen from the mercury will unite with two of sodium, and set free two of chlorine, to combine with one of mercury. As two of soda are produced, these will unite with the two of acid, in the bi-per-sulphate, to form neutral sulphate of soda.

Thus, 1 bi-per-sulphate = { 2 acid; 1 oxid { 2 oxigen; 1 mercury }

2 chlorid of sodium = { 2 chlorine; 2 sodium }

which by decomposition, become

1 bi-chlorid of mercury = { 2 chlorine; 1 mercury }

2 sulph. soda = { 2 acid; 2 soda { 2 oxigen; 2 sodium }

Per-muriate, or rather per-chlorid, as obtained by the process described, is in general in the form of crystallized cakes, requiring 20 of cold and 2 of boiling water for solution. When subjected to heat it is volatilized, and condensed unchanged in its properties. It has a very acrid taste, leaving a disagreeable sensation on the tongue. When swallowed it proves poisonous, inducing sickness and vomiting, accompanied with violent inflammation of the stomach and intestines.

The composition of this substance, considered as a chlorid, has been already given. Of course, when thrown into water, it becomes a per-muriate, and with excess of acid, for the 2 atoms of chlorine must take 2 of hydrogen

to form 2 of acid, while the 2 of oxigen will, with the mercury, form 1 of peroxid.

In solution, therefore, it is composed of

2 atoms acid, 92.5
1 atom peroxid, 270.

Muriate of mercury is decomposed by the fixed alkalies and alkaline earths, which throw down a reddish brown precipitate, but ammonia precipitates it white; the former is considered an oxid, but the latter is a triple *muriate of mercury and ammonia.* It is the *hydrargyrum precipitatum album* of the Pharmacopœia. An economical process for preparing it, is to add ammonia to the fluid from which the precipitated calomel has been thrown down, and which always contains a little per-muriate in solution. *(See Nitrate.)*

Muriate of mercury and ammonia is decomposed by heat, muriate of ammonia is driven off, and the oxid is left pure. It is employed, when mixed with lard, as an ointment.

Muriate of mercury is decomposed also by some of the metals. The action with mercury itself is important, as constituting the process for procuring calomel. For this purpose 4 parts of the salt are rubbed with 3 of mercury, till the whole of the metal disappears, a little water being added, to prevent the powder from rising, and proving injurious to the operator. The product is then placed into an appropriate apparatus, and heated, by which a substance is sublimed and condensed, consisting of three distinct layers, the uppermost of undecomposed muriate, the second of calomel, the lowermost of metallic mercury. The calomel is then removed from the impurities, and again sublimed, after which it is reduced to fine powder, and well washed.

In this process the mercury, during the trituration, combines with the excess of chlorine in the bi-chlorid, and the whole is brought to the state of proto-chlorid. The other steps of the process are merely to make the union more perfect, and to separate the calomel from the impurities, consisting of undecomposed bi-chlorid and of

mercury, the whole of it not having been acted on during the first part of the process.

Corrosive sublimate is used in medicine, in small dozes, as a mercurial; and it is sometimes employed also in vapour, applied to ulcers, as those of the fauces. It is used also, in solution, as a wash. It is useful in preserving anatomical preparations, and in preventing ink from becoming mouldy. It is employed for refining gold and silver, and in giving a coating of mercury to other metals. It is very efficacious in killing bugs.

Ferro-Cyanate.

Ferro-cyanate of potass does not occasion any precipitate from the salts of mercury. When Prussian blue is boiled with red oxid, a hydro-cyanate is formed, which is a valuable substance, because, by its decomposition, it yields cyanogen and hydro-cyanic acid. *(See Iron.)*

Fulminating Mercury.

A compound possessed of detonating properties was discovered by Mr Howard, when making experiments on the red oxid, to which alcohol had been added. The process recommended by him for procuring it is the following. Put an ounce and a half of diluted nitric acid into a flask, and apply a slight heat. Then throw in 100 grains of mercury, and allow the action to go on till the whole of it is dissolved; after which put in two ounces of alcohol, sp. gr. 840, and again apply heat. Etherial fumes are given off, and a powder is gradually deposited. This must be washed immediately with distilled water, and dried by *exposure to air.*

Different opinions have been entertained with respect to the nature of this substance; Howard supposing it a compound of oxid, of mercury, nitrous ether, and oxalic acid; while Berthollet asserted, that it contained the oxid, with ammonia and alcohol. The discovery of cyanogen, and the experiments of Gay Lussac and Leibig, on fulminating compounds, have thrown considerable light on the composition of fulminating mer-

cury. They have found that it is a compound of oxid of mercury, in combination with a peculiar acid, to which they have given the name of *fulminic*, and which contains cyanogen and oxigen, probably also in union with some of the same metal that exists in the oxid, (vol. i. p. 326.) If so, we can easily account for the formation of this peculiar acid, for the nitric acid employed in the solution of the mercury contains nitrogen and oxigen, and the alcohol carbon as one of its ingredients.

According to Leibig, (An. de Ch. et de Ph. xxxiii.) the mercury is in the state of protoxid; for on mixing it with aqua potassæ, a black powder is precipitated. It is decomposed by boiling in water, during which metallic mercury is deposited, and a fulminate with peroxid is formed, and crystallizes when the fluid cools.

Fulminating silver explodes by friction and percussion, and hence the necessity of being cautious during its preparation, particularly in the drying of it. It ought, of course, to be put up in small packets in paper, and kept in separate boxes. It explodes also when touched with sulphuric acid.

It has not yet been decomposed, so as to procure from it its acid; but by treating it with other bases, or with solution of alkali, or lime, the acid is transferred to them, and salts are formed.

Amalgams.

Mercury unites with most of the metals, and forms substances called *amalgams*. They are generally brittle, and if the mercury is in large quantity, are soft, or even fluid. The only amalgam of any use in the arts, containing a metal, the properties of which have been described, is that with tin. It is the substance employed for silvering the backs of mirrors. For this purpose, a sheet of tinfoil is placed on a smooth table of freestone or hardwood, and a little mercury rubbed on it till the whole is amalgamated, after which the plate is put on, and either loaded or kept down by a screw, and by keep-

ing it on an inclined plane, the superfluous mercury is forced out. A resplendent coating is thus given to the glass, and which adheres to it with considerable force.

Some of the metals decompose the mercurial salts. When, for instance, a plate of copper is immersed in the solution of the muriate, it soon acquires a coating of metallic mercury, the copper taking the oxigen from the oxid, and uniting with its acid. Some of the mercurial salts, also, are decomposed by those of other metals. When, for instance, solution of proto-muriate of tin is mixed with that of muriate of mercury, the former becomes per-muriate, uniting with the oxigen and acid of the latter, and metallic mercury is deposited.

Mercury is occasionally, though rarely, found in its metallic state. It occurs chiefly in union with sulphur, in the red sulphuret, or cinnabar, from which it is always obtained; the process for smelting the ore varying in different places. In some cinnabar is exposed to heat, by which the sulphur is burned, and mercury is procured. For this purpose, a long horizontal building is constructed, divided into an upper and under compartment by a grating of iron, on which is placed the ore, broken to small pieces, and covered with bricks made of the ore and clay. Wood is then kindled in the lower compartment, so that the moisture of the cinnabar is expelled, and the sulphur inflamed, after which the fire is extinguished, the heat generated by the combustion of the sulphur being sufficient to drive off the mercury in vapour, which is condensed in a receiver attached to the building. The method practised in other places for procuring mercury is different. The finer part of the ore being separated from the coarser, it is reduced to powder, and mixed with about 1-5th of its weight of slaked lime, and put into iron retorts, each of which holds about half a hundred weight. From 40 to 50 of these are built into a furnace, and heat applied, by which the mercury is given off in vapour, and condensed in receivers. The quantity thus obtained is very

small, which makes the process an expensive one, 100 lbs. of ore yielding only from 6 to 10 oz.

The principal use of mercury is, amalgamating it with other metals, chiefly gold and silver, so as to obtain them pure. *(See Gold.)* It is used also in gilding and silvering, and in making mirrors.

ANTIMONY.

The substance commonly called *antimony*, is a mineral of a dark bluish colour, and possessed of considerable lustre. This is not, however, metallic antimony; it is a sulphuret, and from which the metal is always procured.

Antimony, in its metallic state, is of a whitish colour, and has considerable lustre. It is hard, but brittle; being easily reduced to powder, of course it is not possessed of malleability or ductility. It has a lamellated texture, and often assumes a crystalline appearance. Its sp. gr. according to Berzelius, is 6860; according to Thomson, 6420. Its atomic weight 55. When heated in close vessels, it becomes fluid at about 800; and if allowed to cool slowly, crystallizes in double four-sided pyramids. When the temperature is higher, it volatilizes, and condenses in white scales on the cool part of the apparatus.

It does not suffer any change by exposure to air. When heated in contact with it, it is gradually converted to a greyish powder; and if the temperature be very high, it burns with a bright flame, uniting with the oxigen, and forming an oxid which is wafted up in the same way as that of zinc. This is the substance long known by the name of the *argentine flowers of antimony.*

Oxids.

Various opinions have been entertained with respect to the oxids of antimony. According to Thenard, there are no less than 6; according to Berzelius, 3; while Proust and Bucholz say that there are only 2. Thom-

son, (First Pr.) has shewn that three substances, with oxigen, may be formed; but only two of which are pure compounds, the third being a mixture or compound of the other two, but always in fixed proportions.

Protoxid of antimony is most easily obtained by dissolving the sulphuret in muriatic acid, and precipitating by water, *(see Muriate,)* by which a white powder is formed, which, after being well washed with weak aqua potassæ, and dried by a slight heat, becomes of a greyish colour. It may be obtained also by the addition of ammonia to tartar emetic, (tartrate of antimony and potass,) washing and drying the precipitate. When heated in close vessels, it is fused; but if air be admitted, it is inflamed and volatilized.

According to Berzelius and Dr Davy, it is composed of

metal,	100	=	1 atom,	55
oxigen,	18.6	=	1 atom,	10

This is the only oxid known to enter into union with acids, and form salts; for though antimony can unite with other proportions of oxigen, the compounds seem to be possessed of acid properties. It has been proposed to call them *antimonious* and *antimonic* acids.

Antimonious Acid may be prepared by exposing either the metal or protoxid to a high heat, in contact with air, by which it is inflamed, and the argentive flowers are formed. Or if the compound with the largest proportion of oxigen is heated, it gives off part of its oxigen, and the same substance is produced.

This is much more volatile than the protoxid, insoluble, and not so easily acted on by acids.

According to Berzelius, it is composed of

metal, 100 oxigen, 24.8;

but according to Thomson, of

metal,	100	1 atom, or	2
oxigen,	27.27	1½ atom,	3.

The third compound, the *peroxid*, or *antimonic* acid, is formed by dissolving the metal in nitric acid, evaporating the solution to dryness, and exposing the residue

to a heat of 500, by which a yellow powder is left. This compound, according to Thomson, contains twice as much oxigen as the protoxid. It is composed, therefore, of

metal,	100	1 atom	55
oxigen,	37.2	2 atoms	20

When exposed to a high heat, it gives off part of its oxigen, and becomes antimonious acid.

The compounds of antimony and oxigen are not reduced by exposure to heat alone, they require the presence of inflammable matter, as charcoal.

Antimony does not act on water at a natural temperature; but when steam is passed over it previously heated, oxigen is absorbed, and hydrogen disengaged.

Sulphuret.

The only compound of antimony and a simple acidifiable body of any interest, is with sulphur. The sulphuret may be formed by the direct union of its ingredients; but it is never prepared in that way for use, being an abundant natural production. Native sulphuret is composed of a congeries of spicular crystals grouped together, of a bluish colour, and metallic lustre. It is not, however, a pure sulphuret; it contains silica, lime, and iron, the last in considerable quantity. Hence the necessity of purifying it before it is used for any particular purpose. This is done by melting it in a crucible, in the bottom of which there is a small hole, and placed in another larger one. The fused sulphuret passes through, leaving the greater part of the stony impurities behind. In this state, it is sold under the names of *antimony*, *crude antimony*, and *black antimony*.

According to Thomson, pure sulphuret is composed of

metal,	100	1 atom,	55
sulphur,	36.36	1 atom,	20

Though antimony is easily procured in its metallic state, yet the sulphuret is always employed in the preparation of the different antimonial compounds.

When sulphuret of antimony is exposed to heat, it is

volatilized and condensed, unchanged in its properties; but if air be present, the sulphur passes off in the form of sulphurous acid, and the antimony is oxidated; and if, after this, the heat be raised, the product is fused, and on cooling, forms a brown vitreous substance, commonly called *glass of antimony*. It is merely the oxid fused, but still retaining the impurities of the sulphuret, as lime, siliceous matter, and iron. It is occasionally employed in the preparation of some of the antimonial salts.

Chloruret.

Antimony unites very easily with chlorine. When thrown in powder into the gas, it is instantly inflamed, and produces a chloruret, composed, according to Dr Davy, of

metal,	55	1 atom
chlorine,	45	1 atom.

A similar chlorid may be obtained by distilling 2 of corrosive sublimate with one of metallic antimony, by which a vapour comes off, and, when condensed, forms a soft solid, hence commonly called *butter of antimony*.

Salts of Antimony.

The action between antimony and the acids does not present any thing interesting. By solution in nitric or sulphuric acid, nitrate and sulphate may be formed; but we are very little acquainted with their properties. The salts of antimony are generally procured by the action of the acids on the sulphuret.

Muriate.

Muriatic acid acts very slowly on antimony; but when the sulphuret is used, the action goes on quickly, sulphuretted hydrogen gas is disengaged, and muriate remains in solution. Hence sulphuret of antimony is frequently employed instead of that of iron, in the preparation of sulphuretted hydrogen, using 6 of acid,

and 1 of sulphuret. The muriate left in the retort is of a pale yellowish colour, and will bear dilution with a little water; but if much be employed, it is instantly decomposed, and a white powder is precipitated, which, when dried and boiled in weak solution of potassa, becomes the protoxid, occasionally used in the preparation of some of the antimonial compounds, because it is by far the purest oxid that can be obtained; those procured by other processes, containing the impurities of the sulphuret, which, though dissolved by the muriatic acid in preparing the muriate, are not precipitated when the solution is thrown into water.

The alkalies do not act on antimony. The sulphuret, however, is decomposed by them, and a solution is formed, from which, on cooling, or on the addition of an acid, a brown powder is precipitated. It is the *Sulphuretum Antimonii Precipitatum* of the Edinburgh Pharmacopœia. For preparing it, 4 parts of aqua potassæ, diluted with 3 of water, are boiled on 2 of prepared sulphuret. After the ebullition, having allowed the insoluble matter to fall to the bottom, the clear part is poured off, and diluted sulphuric acid added as long as there is any precipitation. A dark brown powder is formed, which is not a sulphuret, as the name given in the Pharmacopœia would imply, but a *hydro-sulphuret;* for when heated it gives off water, and sulphuret is left. It must contain, therefore, an atom of acid and protoxid; for the water must be formed by an atom of each of its ingredients, while the sulphuret left contains also an atom of each of its constituents.

The formation of this hydro-sulphuret is easily accounted for. The water undergoing decomposition gives hydrogen to the sulphur, and oxigen to the antimony, while the hydro-sulphuret thus formed is held in solution by the potassa. Hence, on the addition of an acid, the alkali is neutralized, and the hydro-sulphuret deposited; there is therefore no disengagement of sulphuretted hydrogen, unless much acid is employed, by which the precipitated hydro-sulphuret is itself decomposed. The

powder thrown down by the addition of an acid, has been long known by the name of *Golden Sulphur of Antimony.*

If, instead of adding an acid, the solution be allowed to cool, a powder of a similar colour, and probably of the same composition, is gradually deposited, the potassa when cold, not being able to keep so much in solution as when warm. The whole of the hydro-sulphuret is not however, thrown down, for on the addition of an acid more is precipitated. The powder deposited on cooling is generally called *Kermes Mineral.*

Antimony and its sulphurets decompose some of the neutral salts. The most important action is that with nitrate of potassa. When antimony and nitre are deflagrated, the oxid in the highest state of oxidation is formed; but this process is seldom followed for preparing it. When the sulphuret is deflagrated with nitre, both the sulphur and antimony acquire oxigen, the former producing sulphurous and sulphuric acid, and the latter protoxid of antimony; the sulphurous acid is expelled, while the sulphuric unites with the potassa to form a sulphate, which is left mixed with the oxid. This constitutes the process of the Edinburgh Pharmacopœia for procuring oxid of antimony, which is used in the preparation of tartar emetic. Equal parts of nitre and sulphuret are deflagrated by throwing them, in small successive portions, into a red-hot crucible.

The product, commonly called *Crocus of Antimony,* is then reduced to powder and washed, to remove the sulphate of potass; what remains is protoxid, but mixed with the impurities of the sulphuret, as the siliceous matter and oxid of iron, the latter of which gives to the tartar emetic prepared from it a brownish tinge. *(See Tartaric Acid.)*

When 3 of nitre and 1 of sulphuret are deflagrated, the combustion is very vivid, the flame acquiring a bluish tinge, and hence the use of antimony in the formation of blue signal-lights. *(See Nitre.)* When 4 parts of salt are employed, the antimony is brought to the highest state of oxidation, forming antimonic acid, which is left

united with potassa; so that the product is an *antimoniate*, (An. de Ch. et de Ph. v.)

Phosphate of Antimony and Lime.

The action between sulphuret of antimony and phosphate of lime, as it exists in bone and horn, is important, as affording a valuable medicine, the *Oxidum Antimonii cum Phosphate Calcis* of the Edinburgh Pharmacopœia, and which is supposed to be the same as the well-known quack medicine *James's Powder.*

For preparing it, equal parts of powder of sulphuret and hartshorn shavings are exposed to heat in an iron ladle, till fumes cease to be given off, and the mixture becomes of an ash-grey colour. This is to be reduced to powder, and exposed in a covered crucible to a strong heat for two hours, by which it becomes quite white.

The horn shavings, besides phosphate of lime, contain animal matter, which by the heat is driven off in the form of carbonate of ammonia, water and carburetted hydrogen, leaving the earthy salt, while the sulphuret undergoes the usual change by heat, becoming an oxid. In the latter part of the process, the oxid and phosphate are made to enter into union, and form a triple phosphate of antimony and lime.

This substance is, when properly prepared, one of the best of the antimonial preparations; but it varies in its composition according to the process followed, and consequently is not uniform in its effects. According to Phillips, (An. of Ph. N. S. iv.) when properly manufactured, it should be composed of phosphate of lime and *protoxid*, whereas it frequently contains the peroxid, and therefore differing from James's Powder, which, from the analysis of Pearson and of Phillips, is composed of

phosphate of lime, 43
protoxid of antimony, 57.

He has found, also, that instead of the oxid and phosphate being in combination, they are frequently merely mixed, and must therefore be totally inert as a medicine. This want of uniformity in the effects of the substance

prepared by the process described, is the cause of James's Powder being preferred by most practitioners.

Alloys.

Antimony forms alloys with a number of the metals, the most important of which are those with lead and tin.

When equal parts of metallic antimony and lead are melted, the product, when cold, is porous and brittle; but as the proportion of the latter is increased, the brittleness is diminished. When 1 of antimony and about 4 or 5 of lead are fused, they form *type metal*, which is harder than lead, and possesses the valuable property of expanding during its congelation; hence it takes an excellent impression, when thrown fluid into a mould. Owing to this, it is also occasionally used for taking casts from medals.

Antimony combines also with tin, and forms one sort of pewter. The name of *pewter* is given to any white malleable alloy, containing a considerable quantity of tin; but its composition varies in different places. The finest kind is composed of about 100 parts of tin, 8 of antimony, 4 of copper, and 1 of bismuth, the use of which is to render the tin harder, and enable it to retain its lustre. The alloy of tin and antimony forms also the metal on which music is engraven.

Antimony is found native, though rarely so. Its principal ore is the sulphuret, and from which it is always procured. It is first purified by the process already described, and then converted to oxid by exposure to heat and air, the temperature towards the end of the process being increased, so as to drive off the whole of the sulphur. The oxid is then exposed to heat with charcoal, by which the oxigen is abstracted, and the metal reduced, and when fluid, falls to the bottom of the vessel.

Antimony is used chiefly in the formation of types and music metal. Its oxid, prepared by deflagrating the sulphuret with nitre, is employed for giving a yellow colour to earthen-ware; and the purer oxid, obtained by precipi-

tation from the muriate, is used for making yellow glass, and hence its use in imitating some of the gems.

MANGANESE.

The substance commonly called *manganese*, was, till about the middle of the last century, considered an ore of iron, and was by mineralogists placed in that order.

Scheele and Bergman shewed, however, that it contained a peculiar metal, and which was afterwards procured by Gahn in its separate state, who gave it the name of manganese, and the ore from which it was obtained was found to be an oxid.

Manganese is of a whitish colour, resembling that of recently broken cast iron, having a granular texture, and considerable lustre. It is not possessed of malleability nor ductility. When pure it is not attracted by a magnet, but a very minute quantity of iron gives it magnetic properties. Its sp. gr. is 8000. Its atomic weight 35.

When heated to 160 W. it is fused. By exposure to air it very quickly absorbs oxigen, and becomes an oxid, acquiring different colours, according to the quantity absorbed, as grey, violet, brown, and lastly black.

Oxids.

Very different opinions have been entertained with respect to the nature of the oxids of manganese. Dr John (An. of Ph. ii.) imagines that there are three, a *green*, a *brown*, and a *black*, the composition of which is,

1 metal,	100	oxigen,	15
2	100		25
3	100		40.

The experiments of Berzelius, (An. de Ch. lxxxvii.) of Forchhammer, (An. of Ph. xvi.), and of Thomson, (First Pr.) prove satisfactorily, that there are at least five compounds, three oxids, and two possessed of acid properties.

Protoxid may be obtained by exposing the deutoxid

to a red heat, and passing hydrogen gas over it, by which part of the oxigen is extracted. It is of a green colour, but it very soon changes by exposure to air, absorbing oxigen, and becoming deutoxid. According to Thomson, it is composed of

metal,	100	1 atom	35
oxigen,	28.56	1 atom	10.

Deutoxid may be prepared by exposing the pure black or native oxid to heat, by which part of the oxigen is expelled, and a brownish powder is left. It is soluble in muriatic and sulphuric acids, without effervescence, and forms red solutions. Or it may be procured by exposing the proto-carbonate to heat and air, to expel the acid, and allow the absorption of oxigen.

According to Thomson, it is composed of

metal,	100	1 atom or 2
oxigen,	42.84	1½ atoms or 3.

Peroxid is the same as the native black oxid, except that in the latter there are, in general, impurities, as carbonate of lime, oxids of iron, copper, and lead, and frequently also baryta. Some specimens, however, are pure oxid; and it was by an examination of them, that Dr Thomson was enabled to ascertain its composition. Black oxid may also be obtained by digesting the deutoxid in nitric acid, by which protoxid is dissolved, and peroxid left.

According to Thomson, it contains double the quantity of oxigen that exists in the protoxid. Its composition is therefore,

metal,	100	1 atom	35
oxigen,	57.12	2 atoms	20.

Besides these, other compounds exist, but possessed of acid properties, and called *manganesious* and *manganesic acid.* They will be described when detailing the action of nitre on the black oxid.

The only oxid of any interest is the black oxid, which, being a native production, is applied to many useful purposes.

When exposed to heat it is decomposed, being reduced

from tritoxid to deutoxid, and oxigen gas is disengaged; and hence the method by which this elastic fluid is generally prepared, when required in large quantity. For this purpose the ore, reduced to coarse powder, is put into an iron retort, which must be brought to a red heat by placing it in a common fire or furnace. At first a little watery vapour and carbonic acid gas come off, after which the oxigen makes its appearance, and which is known by collecting a little of it in a phial, and testing it with a piece of wood recently extinguished. When coming off sufficiently pure, the mouth of the retort must be connected with a gas-holder, and the heat continued till it ceases to be disengaged.

The quantity of oxigen obtained from the ore by this process depends on its purity. The utmost that can be got, supposing the oxid pure, is about 12 per cent. or 1-8th of its weight, but making allowance for impurities, we are not to expect even from good specimens more than 10 per cent.; so that a pound may yield about a cubic foot.

Manganese does not present any thing interesting in its action with simple acidifiable bodies.

Salts of Manganese.

It unites with the acids, and forms some important compounds; but we are little acquainted with the action between metallic manganese and the acids, the black oxid being always employed in the preparation of its salts, and which in general contain the protoxid; so that the native oxid must, during the action, undergo decomposition.

Nitrate.

Nitric acid acts very slowly on the black oxid, but if *nitrous* be used, it acquires oxigen from it, reduces it to the state of protoxid, and then combines with it. The same will happen if nitric acid be employed and exposed to the sun's rays, by which it is changed to nitrous,

and then acts as already described; or if any substance, as sugar, that will de-oxidize the oxid, be mixed with the acid, a nitrate will be obtained. The solution is colourless, and by cautious evaporation, affords crystals composed of 1 atom of acid, 1 of protoxid, and 7 of water.

Carbonate.

This salt is always prepared by the addition of an alkaline carbonate to a solution of the nitrate, muriate, or sulphate, by which a white powder is deposited. When kept at a red heat for a long time exposed to air, the acid is expelled, and oxigen absorbed; by which it becomes a deutoxid. Its constituents, according to Thomson, are 1 atom of acid, 1 of oxid, and 2 of water.

Sulphate.

Concentrated sulphuric acid at a natural temperature scarcely acts on metallic manganese, but when diluted, a sulphate is formed, the metal being oxidated by the water. A similar salt is produced by the action of the acid on the protoxid or carbonate. Even when the deutoxid is employed, the protoxid of it is dissolved, and the peroxid is left.

Proto-sulphate of manganese is of a pale reddish colour, and crystallizes in oblique prisms. It is soluble in about $2\frac{1}{2}$ of cold water, giving a pale red solution, which is easily decomposed by the alkalies, alkaline carbonates, and phosphates, and hence a method of preparing some of the insoluble salts.

It is composed, according to Thomson, of

acid, 33 = 1 atom
oxid, 30 = 1 atom
water, 37 = 5 atoms.

By far the most important action of sulphuric acid is with the native black oxid. When the concentrated acid is poured on it, there is no action, provided the oxid is pure; but there is frequently a disengagement of carbonic acid, owing to its containing carbonate of lime. On

the application of heat, oxigen gas is evolved, and sulphate is formed. Hence the method generally practised for procuring oxigen gas on a small scale, and when not required very pure. For this purpose equal weights of the acid and powder are put into a retort, and thoroughly mixed, to prevent the oxid from running into hard lumps. Heat is then applied by means of a lamp, or chauffer, and the gas collected over water. As carbonic acid is apt to be given off in this case, it is necessary to test the gas before beginning to collect it in the jars, and which is done in the usual way, by putting into a small phial of it a piece of wood, the flame of which has just been extinguished.

In this experiment the oxid is decomposed, and converted, by the expulsion of part of the oxigen gas, into deutoxid, which, uniting with the acid, forms a sulphate; so that the same quantity of oxigen is given off by this process, as by the decomposition by heat. The product yields a solution of a deep red colour.

Muriate.

Muriatic acid dissolves manganese, with the disengagement of hydrogen gas; but the muriate is seldom prepared in that way, being easily obtained by the action of the acid on the native oxid, in which case chlorine gas is disengaged, and hence the method commonly practised in preparing it. For this purpose 1 part of the powder of the oxid, with 4 of acid, are put into a retort, and a slight heat applied. The gas very soon comes off, and may be collected over water; but, as it is absorbed when the temperature is low, it is necessary to have the fluid in the trough heated to about 60 or 70. Unless required for immediate use, it ought to be collected in wide-mouthed bottles, the stoppers of which being introduced before removing them from the trough, are afterwards to be secured by wax luting, and in this way the gas may be kept for any time. During the action of the acid on the oxid, both undergo decomposition; the hydrogen of part of the latter unites with the excess of oxi-

gen of the former, to generate water, while the chlorine, the other ingredient of the acid, is set free. The remainder of the acid unites with the protoxid, and forms proto-muriate *. The residue in the retort, when filtered, yields a brownish solution, which may be made, though with difficulty, to crystallize. Like the other salts, it is decomposed by the alkaline carbonates, phosphates, &c. It is composed of

acid, 34 = 1 atom
oxid, 33 = 1 atom
water, 33 = 4 atoms.

When chlorine is prepared on a large scale, as in the manufacture of the bleaching compound, instead of oxid and muriatic acid, a mixture of equal parts of oxid, sulphuric acid, and sea salt is employed, by which the preparation of the muriatic acid is avoided, because the oil of vitriol sets it free from the sea salt, which, acting on the oxid, gives off its chlorine just as when muriatic acid alone is used.

Acids of Manganese.

The alkalies do not act with metallic manganese; but the action with the black oxid is peculiar. When 1 of oxid is heated with about 5 of caustic potassa, a dark green-coloured substance is formed, discovered by Scheele, and to which he gave the name of *Mineral Chameleon*, from the change of colours it assumes when acted on by air and water. When a little water is thrown on it, it forms a deep green solution, a little more makes it blue, and by continuing the addition, it becomes purple, and lastly red. At first there is a precipitation of a yellowish powder, and after the fluid has become red, black oxid gradually makes its appearance, and the colour disappears. Mineral chameleon gives different coloured solutions also, according to the temperature of the

* According to the old doctrine, the oxigen disengaged from the oxid uniting with part of the acid, converts it to *oxi-muriatic acid*, while the proto-muriate remains in the retort.

water. When hot water is poured on it, the colour is green, but with cold water it is red. If, along with the water, any substance be added, which has a powerful affinity for oxigen, as sulphuretted hydro-sulphuret of potass, the compound loses the property of changing its colour.

Though mineral chameleon can be prepared by the action of potass, other means have been pointed out. That usually followed is with nitre. For this purpose, a mixture of 3 of nitre and 1 of oxid is thrown into a red hot crucible, and kept for some time in a state of fusion. The product when cold is removed, and put into well-stoppered phials.

It was at one time supposed that this peculiar substance was a compound of the alkali and oxid, and that the changes were owing to the absorption of oxigen; but it is now known, that during its preparation the oxid acquires more oxigen, passes into the state of an acid, and then unites with the potass. Chevillot and Edwards, (An. de Ch. et Ph. viii.) by the evaporation of the red solution, procured red-coloured crystals, possessed of remarkable properties. They are soluble in water; have a sweetish taste. When heated in contact with hydrogen, they cause it to inflame. They act also on phosphorus, carbon, and sulphur, nearly in the same way as chlorate of potass, causing explosion. It has been ascertained by the experiments of the above-mentioned chemists, confirmed also by those of Forchhammer, (An. of Ph. xvi.) that these crystals contain potassa in union with an acid, composed of manganese and oxigen, but with the latter in larger quantity than exists in the black oxid; so that in the preparation of the mineral chameleon, the oxid mus thave acquired oxigen from the nitre, while the acid thus formed has entered into union with the potassa. According to Forchhammer, there are two acids of manganese, a *manganesious*, and a *manganesic* acid; the latter having the largest proportion of oxigen. The green-coloured compound formed by the action of nitre on the oxid, contains the alkali in union with the

former, and is therefore a *manganesite* of potassa; while the red crystals are *manganesiate*. If this is really the case, the change of colour of the mineral chameleon is owing to the absorption of oxigen, for the solution which is at first manganesite gradually becomes manganesiate, from the acquisition of oxigen from the atmosphere.

Forchhammer has endeavoured to ascertain the composition of these acids, but the conclusions deduced from his experiments must be received with caution. He supposes the former to contain 1 atom of manganese and 3 of oxigen, and the latter 1 to 4.

Ammonia acts also on the black oxid, but the action is very different from that of the fixed alkalies. When the gas is passed slowly over the oxid at a high temperature, nitrous acid is generated. For performing this experiment, an earthen tube, stuffed with pieces of oxid, is made incandescent, by passing it through a chauffer. In the retort is placed a mixture of muriate of ammonia and lime, and when the oxid is properly heated, heat is applied to the retort, to expel the ammonia. A receiver is placed on the opposite end of the tube, and which soon becomes full of the red fumes of nitrous acid.

The explanation of this action, which, when discovered, appeared so remarkable, is very simple: the oxigen from the oxid, expelled by the heat, decomposes the ammonia, part uniting with the hydrogen to form water, and part with the nitrogen to generate nitric oxid, which, with the oxigen of the atmosphere, produces nitrous acid.

If the gas be passed quickly over the oxid, nitrate of ammonia is the result.

Some of the compound salts act with the black oxid. The action with nitre has been already explained. That with borax, or phosphate of soda, is also peculiar. When either of these is melted along with the oxid, by a blow-pipe, it acquires a reddish tinge when held at the extremity of the flame, but when brought to the point of the blue flame, the colour disappears; changes which may be effected any number of times, and seem to depend on the oxidation of the manganese, probably the formation

of its acids. Hence this has been proposed as a test of the presence of this metal in ores.

When oxid of manganese is fused with glass, it makes it of a purple colour, and hence its use in imitating some of the gems.

The alloys of manganese have been but very little examined.

The principal source of manganese is the black oxid, from which it is always procured. The process for obtaining it is complicated, because the native oxid contains in general so many foreign ingredients; perhaps the best is that recommended by Faraday, (Lond. Journ. vi.) When the oxid is heated with muriate of ammonia, chlorine is disengaged, which, acting on the manganese, forms with it a chlorid, so that, by putting this into water, muriate is obtained, which, on the addition of an alkaline carbonate, yields carbonate of manganese. After this has been heated to expel the acid, it is mixed with oil, and again heated, by which the oxigen is withdrawn, and the metal is left pure.

Metallic manganese is, however, seldom employed, the oxid, by its decomposition, affording the different compounds. The oxid is employed abundantly by chemists, and in the arts. Its use in the preparation of oxigen and chlorine, have just been noticed. When describing the manufacture of earthen-ware and glass, its use in communicating to the former a brown colour, and in rendering the latter colourless, have been explained, (vol. i. p. 507.)

GOLD.

Gold has been long known. Its scarcity, and its superior metallic properties, render it the most valuable of the metals. When pure, it is of a reddish yellow colour, with considerable lustre, which is not liable to be altered by exposure to air. Its sp. gr. is 1930. Its atomic weight, according to Thomson, is 250. It is soft, but is far superior in malleability and ductility to the other metals. One grain can be beat to leaves of about

1-280,000th of an inch in thickness, and will cover 56 square inches. By putting gold on silver, and drawing it to wire, it may be still farther extended, for the whole of the silver still retains a coating of gold, which is only 1-12th part of the thickness of the leaf. One grain, it is said, may be in this way drawn out to about 2 miles and 3-4ths in length.

The ductility of gold is also very great, being easily drawn to wire finer than that of any other metal. Its tenacity is also considerable, a wire of about the 1-13th of an inch in thickness bearing a weight of 150 lb. without breaking.

Gold melts at 32 W. (5237 F.) and during its fusion it enlarges, consequently it shrinks when it congeals. In its liquid state, it is of a bright green colour.

It is one of the metals that are not affected by heat and air. When subjected to a high temperature, in contact with it, it does not suffer any change; but it can be oxidated by electricity, by which an oxid of a purple colour is formed.

Oxids.

It unites with two proportions of oxigen. The *protoxid* is of a greenish colour, and the *peroxid* is purple. The former may be obtained by dissolving the metal in aqua regia, evaporating the solution to dryness, and treating the residue with potassa, by which a green powder is precipitated. When this is kept for some time, it is decomposed, part of it takes oxigen from the other, the former becoming peroxid, and the latter metallic gold, and hence a method of preparing *peroxid.* The peroxid may also be procured by the addition of potassa or magnesia to the muriate, and washing the precipitate with water and nitric acid, to remove impurities. It is of a purple colour. By the application of a strong heat, the whole of the oxigen is driven off, and the metal is left pure.

Different statements have been given of the composition of the oxids. According to Berzelius, the protoxid consists of

metal,	100	1 atom,	250
oxigen,	4	1 atom,	10

and the peroxid, of

metal,	100	1 atom,	250
oxigen,	12	3 atoms,	30

Chlorid.

The only action of any importance between gold and simple acidifiable bodies, is with chlorine. When gold leaf is introduced into the gas, it is instantly inflamed, and a chlorid formed. If the leaf be put into a solution of chlorine in water, or if a stream of gas be passed through water, holding the leaf suspended in it, it is dissolved, first becoming chlorid, and then probably muriate.

Muriate.

Gold differs from the other metals already described, in resisting the action of acids; even nitric, which acts so powerfully on them, has no effect on it. The substance which dissolves it most easily, is aqua regia, or nitro-muriatic acid, the solvent power of which, though it was at one time supposed to depend on the oxidizing agency of nitric acid, is now known to be owing to the presence of chlorine, and by which a chlorid, and ultimately a muriate, is formed, the former being decomposed by the water existing in the acid fluid.

The want of action between the acids and gold, and the power of aqua regia to dissolve it, are well illustrated by putting some gold leaf into nitric and into muriatic acid, in separate flasks, and afterwards mixing the fluids with the metal in them. In the first instance, there is no action whatever; but in the latter, the leaf almost instantly disappears. When gold is kept for some time in aqua regia, (2 muriatic and 1 nitric acid,) slightly heated, it is gradually dissolved, affording a solution of the muriate, of a yellowish colour, and from which any excess of acid can be expelled by boiling. By evaporation, yellowish crystals of chlorid of gold are de-

posited. When these are slightly heated, they undergo decomposition, part of the chlorine being evolved, and another chlorid formed. The last of these is composed of

gold, - 100
chlorine, 14.715

and the latter, supposed to contain

gold, - 100
chlorine, - 44.145;

so that the one probably contains an atom of each, and the other 1 atom of metal to 3 of chlorine.

When the chlorid is strongly heated, the whole of the chlorine is evolved, and metallic gold is left.

Water dissolves the perchlorid, but decomposes the proto-chlorid, causing the chlorine to pass from one part to the other, by which metallic gold and perchlorid are formed.

Muriate of gold is decomposed by some of the simple acidifiable bodies, provided moisture is present. Thus, when a piece of cloth, soaked in the solution, is exposed to hydrogen gas, it becomes covered with a thin film of gold, and hence a means of gilding cloth, either entirely or partially; for if traces be drawn on it with a hair pencil, and exposed to a stream of hydrogen, the gold is deposited only on those parts covered with the solution. The muriate is decomposed also by carbon and phosphorus, which, when immersed in it, cause the deposition of metallic gold, (Fulhamme on Combustion.)

The fixed alkalies decompose the muriate, throwing down a yellowish red precipitate, which is almost entirely re-dissolved if an excess be employed. The solution is of a greenish colour, and contains the alkali in union with the oxid, but supposed here to act the part of an acid; and hence it has been proposed to call it *auric* acid, and the compound in solution *aurate* of potassa.

Fulminating Gold.

The action between the muriate and ammonia, is interesting, as affording a means of preparing a fulminating compound. To obtain it, add aqua ammoniæ to a dilute

solution of the muriate, as long as it occasions precipitation. Collect the powder on a filter, wash it, and dry by exposure to air. Fulminating gold is of a reddish yellow colour. It detonates with considerable violence by friction and percussion, and also by the application of a heat of about 250. Hence the necessity of using but a very small quantity of it, a grain being quite sufficient. Of course, in keeping it, it ought to be put into bottles with *corks*. When detonated so as to collect the products, they are water, nitrogen, and metallic gold.

The composition of this substance has not been ascertained, but it is supposed to be a compound of ammonia and the oxid; hence, when decomposed, the hydrogen of the latter will unite with the oxigen of the former, to generate the water, disengaging nitrogen and gold in its metallic state.

Muriate of Gold and Soda.

Muriate of gold is acted on by some of the neutral salts. When a muriate, as that of soda, is added, and the solution is cautiously evaporated, it yields prismatic crystals of an orange colour, and which have been found by Dr Thomson to contain perchlorid of gold, chlorid of sodium, and water; or they may perhaps, with more propriety, be considered a compound of muriate of gold and of soda with water of crystallization. The composition, according to him, is

bi-chlorid of gold	1 atom
chlorid of sodium	1 atom
water	8 atoms

or muriate of gold 1 atom = { 2 acid, 1 peroxid

muriate of soda 1 atom = { 1 acid, 1 soda

water 5 atoms

the three atoms of hydrogen, from the 3 of water, having with the chlorine formed 3 of acid; while the 3 of oxigen have produced 1 of peroxid of gold, and 1 of soda.

Muriate of gold is decomposed by some of the metals and their salts. Those which have a strong attraction for oxigen, decompose its oxid, and unite with its acid. Hence iron, zinc, copper, and mercury, put into the solution, cause the deposition of metallic gold. Other metals, on the contrary, cause the deposition of the gold, mixed with the oxid of the precipitating metal. When, for instance, pieces of tin leaf are kept in the solution for some time, a purple powder is gradually formed, long known by the name of the *purple powder of Cassius.*

Many of the metallic salts also decompose muriate of gold, particularly those containing protoxids, the metal of which has a strong attraction for oxigen. Green vitriol, for instance, throws down the gold in its metallic state, the iron depriving the oxid of its oxigen, and becoming a peroxid, so that per-sulphate remains in solution.

The action with proto-muriate of tin is also important. When added to the muriate, the purple powder of Cassius is formed. For preparing it, tin is dissolved in a mixture of 2 parts of nitric, and 1 of muriatic acid, without the application of heat, so as to have it in the state of proto-salt, after which it is mixed with the solution of the muriate, by which the purple powder is deposited. It is then to be thrown on a filter and washed. It may be prepared, also, and perhaps purer, merely by keeping some pieces of tinfoil, or of grain tin, in the solution of gold, and the powder is gradually formed.

Different opinions have been entertained with respect to the nature of this substance. According to some, it is a mixture of peroxid of tin and protoxid of gold; while, according to others, the gold is in its metallic state. When melted with glass, it gives it a rich red colour, and hence its use in imitating some of the gems.

Muriate of gold is employed for giving a coating to other metals, particularly iron. This is done by diluting the solution with spirit of wine, and putting the iron into it, its surface being previously well polished. In the

course of a short time, it acquires a covering of gold, which may be made to adhere firmly by burnishing. Instead of spirit of wine, ether is sometimes employed. The solution of the muriate being evaporated to dryness, the residue is dissolved in ether, into which the iron is immersed, and almost instantly removed. By exposure to air the ether evaporates, and leaves the gold adhering to the iron, so that, by repeating the process, a sufficiently thick coating may be given to it. In this way finer sorts of instruments are sometimes gilded, more particularly if they are likely to be exposed to moisture, by which they are prevented from being rusted.

Muriate of gold is also employed in porcelain painting; for which purpose it is mixed with borax and gum, and applied to the ware by means of a hair pencil. By the application of heat, the part covered with it acquires a rich red colour.

Alloys.

Gold combines with other metals, and forms useful compounds, the most important of which are those with copper and mercury. When alloyed with the former, it acquires the valuable property of becoming harder, owing to which it is mixed with it when employed for making coins. From the experiments of Hatchet, (Ph. Tr. 1803,) it has been ascertained, that the hardest alloy is that composed of 11 of gold and 1 of copper. Hence, by order of Government, *Standard* or *Sterling Gold* contains a twelfth part of its weight of copper. Coins made of this are harder than those of pure gold; hence the impressions on them continue much longer entire. Jewellers' gold contains more of the alloying metal, and sometimes, instead of copper, a mixture of it and silver is used, the latter giving to the compound a colour more nearly the same as that of pure gold, while copper alone makes it darker. Hence its frequent use in making trinkets.

There exists a strong attraction between gold and mercury, so that they can be easily amalgamated. When a piece of gold is dipt into mercury, it merely acquires a

white colour; but, by putting it when red hot into the other brought nearly to its boiling point, a soft amalgam is formed, from which the superfluous mercury can be removed, by squeezing it in a leather bag. By this means a substance is obtained, consisting of about 1 of gold and 2 of mercury, and from which the latter is easily driven off by heat; hence its use in gilding.

Though the alloys of gold and the other metals already described are not put to any use, yet it is important to know, that many of these impair materially its properties. Thus 1-2000th part of lead sensibly affects it, and by merely exposing it to its vapour, its ductility is considerably diminished. When the lead amounts to about 1-12th part, the alloy is as brittle as glass.

Tin and antimony also impair its properties. It is necessary, therefore, when it is to be alloyed with copper or silver, that these be quite pure; and particular attention must be paid to this, with respect to the latter, because the ores from which it is procured often contain lead.

Gold is a very sparing production of nature. It is always found in its *metallic* state, either pure, or in combination with some other metal. In almost all civilized nations, it is used as a medium of exchange.

It is used also extensively in gilding other metals, and also wood, paper, and glass, for which purpose it is employed in leaf, in powder, and in amalgam. For procuring gold leaf, it is fused along with borax, and cast into an iron mould previously greased, after which it is heated, to burn off the tallow, and extended by beating, and by passing it between rollers, till it becomes as thin as paper. It is then cut into pieces of equal size, and again hammered between slips of ox-gut, till they become of the requisite thinness, after which they are put up in books, the paper being covered with red bole, an impure sort of alum, to prevent them from adhering to it. In this operation, each grain affords about 30 inches of leaf, which is only about 1-180,000th of an inch in thickness. Gold powder is prepared by dissolving the metal in aqua regia, and putting into the solution a piece of

copper, which unites with its oxigen and acid, and causes it to be deposited in its metallic state in fine powder, after which it is kept for some time in warm vinegar, washed, and dried by heat. Gold powder is also procured by heating its amalgam, by which the whole of the mercury is expelled, and by stirring it during the application of the heat, to prevent it from running together. It is then rubbed in a mortar with water, and dried. The mode of procuring the amalgam has been already described.

The process of gilding differs according to the substance to be gilded. For paper and wood, gold leaf is almost always employed, the surface being covered with some adhesive matter. For metals, the amalgam is generally used. When silver is to be gilded, after being washed with muriatic acid, its surface is covered with the amalgam, and then, by placing it on a charcoal fire, the mercury is driven off, and the gold left adhering to the silver. The loose particles are removed by a brush, and after covering it with gilder's wax, a composition of bees' wax, red ochre, verdigris, and green vitriol, it is heated and plunged while warm into cold urine, by which the colour is heightened.

As copper is not easily acted on by gold amalgam, it is necessary to communicate to it a thin layer of mercury, which is done by immersing it in a solution of the nitrate, by which the mercury is deposited in its metallic state, and adheres to the copper. It is then gilded by means of the amalgam, the thin layer of mercury enabling it to retain the gold. Gilding of glass and porcelain is usually done by means of a flux, as borax. For this purpose the gold powder is mixed with gum and borax, and applied by means of a pencil. The ware is then heated, by which the gum is burned off, and the borax melted, causing the gold to adhere to it.

For the method of procuring gold, *see Silver.*

SILVER.

Silver resembles gold in many of its properties, more particularly in its malleability, ductility, and power of resisting the action of most acids. When pure, it is the whitest of metals, and is possessed of considerable lustre. It is harder and more elastic than gold, and next to it in malleability and ductility. It may be beat to leaves of only 1-160,000th part of an inch in thickness, and it can be drawn out to wire finer than a human hair, the tenacity of which is considerable. When of about 1-10th of an inch, it will sustain a weight of 300 lbs.

Its sp. gr. is 1050. Its atomic weight 137.5.

Silver melts at 22 Wedgewood; and if the heat be higher, it boils, and is dissipated slowly in vapour. When in fusion, it becomes very resplendent; and if allowed to cool slowly, it assumes a crystalline form.

By long exposure to heat and air, it is converted into an oxid; but the oxidation goes on very gradually. When subjected to the oxi-hydrogen blow-pipe, it burns with a greenish flame. When also electric sparks are passed through it, in the state of wire or leaf, or when subjected to the action of galvanism, an oxid is formed.

Oxid.

Though oxid of silver can be formed by the methods mentioned, it is much more easily procured by dissolving the metal in nitric acid, and adding lime or baryta, by which an olive-coloured powder is precipitated.

The different statements given of its composition, all very nearly agree. Taking the average, it is composed of

	metal,	100	
	oxigen,	7.34;	
1 atom,	137.5	or	100
1 atom,	10		7.27

Sulphuret.

When silver is long exposed to air, it is tarnished, owing to the sulphureous vapours constantly floating in the atmosphere, by which a sulphuret is formed. The same sulphuret may be procured by heating sulphur and silver together, or by the transmission of sulphuretted hydrogen through a solution of one of its salts. It is black and soluble in acids, giving off sulphuretted hydrogen gas. It is composed of

metal,	100	1 atom,	137.5
silver,	14.9	1 atom,	10

Chlorid.

Silver unites very easily with chlorine. When introduced into the gas, it slowly absorbs it, and a white substance is formed. The chlorid is, however, most easily obtained by the addition of any muriate, as of soda, to the solution of the nitrate, by which the nitric acid and soda unite, while the oxid of silver and muriatic acid undergo decomposition, the oxigen and hydrogen forming water, and the chlorine and silver the chlorid. It is in the state of a white powder, but becomes black on exposure to light; and that this is the cause of the blackening, is proved by keeping the glass containing the precipitate in the dark, by which it retains its whiteness. If exposed to sunshine, it is almost instantly blackened.

When heated to about 500, it is fused; and on cooling, it becomes grey, and semi-transparent, resembling a piece of horn, and hence called *luna cornea.* By a much stronger heat it is decomposed. It is soluble in ammonia; but the alkaline carbonates, by the aid of heat, decompose it, reducing it to its metallic state; and hence the method of procuring pure silver, by precipitating the chlorid, washing it with nitric acid, and then exposing to heat in a crucible, with bi-carbonate of potass. It is also easily decomposed by some of the metals, as

zinc, which, when heated slightly with it, deprives it of its chlorine, and sets free the metallic silver.

Numerous experiments have been made by Proust, Rose, Berzelius, Marcet, Gay Lussac, Dr Davy, and Thomson, with the view of finding the proportions of the ingredients of this chlorid, not only as affording the best means of fixing the atomic weight of silver, but because, by the precipitation of chlorid from any fluid containing muriatic acid, it affords a method of finding the proportion of that acid that existed in solution.

Its composition is, according to

	Davy.	Thomson.
silver,	100	100
chlorine,	32.5	32.7;

which last makes it exactly an atom of each, so that we may consider it as correct. Were we to suppose this in the state of muriate, we easily find the muriatic acid equivalent to the chlorine, and can thus know how much acid any fluid contains; 100 gr. of chlorid, the preceding statement shews, contain 75.4 of silver, which require 5.5 of oxigen for oxidation, forming 80.9 of oxid, and deducting this from 100 leaves 19.1; so that 100 of chlorid are equivalent to 19.1 of muriatic acid.

Nitrate.

Very few of the acids act upon silver. The one that dissolves it most easily, is nitric acid; indeed it is necessary to have it diluted, to moderate the action, which is accompanied with the usual phenomena, the disengagement of nitric oxid, and formation of nitrate. The solution is transparent and colourless, provided the substances are pure; but if the acid has contained a little muriatic acid, it is turbid from the deposition of chlorid of silver. If, on the other hand, standard silver be used, the solution is of a greenish tinge, from the formation of nitrate of copper. By evaporating the solution, flat rhomboidal crystals of nitrate of silver are obtained. They have a bitter taste; are easily fused by the application of heat, in which state it is poured into cylindri-

cal moulds, and forms *lunar caustic*. During the fusion, however, it seems to undergo a slight change; it acquires a dark colour, and it is not completely soluble in water, probably from the decomposition of a little of the nitrate, its acid being expelled.

When the solution of the nitrate has been prepared from Sterling silver, the copper is easily removed by evaporating to dryness, and exposing the residue to heat, by which the acid is expelled from the copper, and the oxid left, and as it is insoluble, the nitrate of silver is easily taken up by water.

Nitrate of silver is dissolved by about an equal weight of cold water. The solution is transparent and colourless, but on exposure to light, undergoes decomposition. If, for instance, traces be drawn with it on paper or cloth, and exposed to sunshine, they very soon become black. Hence its use as *indelible* or *marking ink*. For preparing this, a piece of pure silver is put into its own weight of nitrous acid, diluted with an equal quantity of water; and when the acid has taken up as much of it as it can, which is known by its ceasing to give off bubbles of gas, it must be poured off, and evaporated to dryness, and then fused by continuing the heat. Two parts of the dried residue, and 1 of gum Arabic, are dissolved in 7 of water, and the solution blackened with a little China ink; but before applying it to the cloth, this must be wetted with an alkaline solution, (prepared by dissolving an ounce of carbonate of soda, and 1-4th of an ounce of gum Arabic, in four ounces of water,) and then dried.

Nitrate of silver is decomposed by some of the inflammables, as hydrogen gas, carbon, and phosphorus, the action being exactly the same as already mentioned with gold, the silver being deposited in its metallic state.

It is decomposed by muriatic acid, which precipitates the chlorid, by the fixed alkalies which throw down the oxid, and by the muriates, phosphates, and carbonates. Ammonia at first occasions a precipitate, but almost instantly re-dissolves it; and hence the method of preparing the *ammoniuret* of *silver*, or *nitrate* of *silver and am-*

monia, merely by adding aqua ammoniæ to the solution of the nitrate, till the precipitate at first formed disappears. The solution is transparent and colourless.

Nitrate of silver is also decomposed by some of the metals. When, for instance, a plate of copper is immersed into its solution, it very soon acquires a coating of silver, and leaving it there for some time, the whole of the silver is deposited in the form of a light flocculent powder. It is not pure, but can be purified by throwing it into another solution of the nitrate, which removes any copper mixed with it.

When mercury is put into the solution, the silver is precipitated, and if the action go on slowly, and the vessel be kept undisturbed, the metal assumes a dendritic appearance, the branches spreading through the solution. Hence the mode of forming the *Arbor Dianæ*, merely by throwing a globule of mercury into very much diluted nitrate of silver. The action here by which the metal becomes arborescent, is to be explained in the same way as in the formation of the lead tree, (p. 46.) Nitrate of silver is, according to Thomson, composed of

acid,	32	1 atom
oxid,	68	1 atom

Phosphate.

Phosphoric acid does not act on silver. A phosphate may, however, be prepared by the addition of phosphate of soda to nitrate of silver, by which a yellow powder is precipitated. When boiled with any earthy muriate, it is decomposed, and phosphate of the earth and chlorid of silver are formed; and hence the use to which Gay Lussac applied it, in freeing chlorate of baryta from the muriate, with the view of procuring chlorate of baryta, from which he obtained chloric acid, (vol. i. p. 476.)

Sulphate.

Sulphuric acid does not act on silver in the cold, but by the application of heat a sulphate is formed, the metal being oxidated by part of the acid. It may also be

procured by adding an alkaline carbonate to the nitrate, to throw down carbonate of silver, and then decomposing this by sulphuric acid. The sulphate is sparingly soluble, requiring about 90 of cold water for solution. At a red heat it is decomposed, the acid being expelled, and the oxid reduced. The alkaline earths, the carbonates, muriates, and phosphates, also decompose it.

Arsenite.

When arsenite of potass is mixed with nitrate of silver, a yellow precipitate of arsenite of silver is formed; and as the nitrate is so easily decomposed by the arsenical salt, it has been recommended as a test of arsenic. *(See Poisons.)*

Fulminating Silver.

Different methods are followed in the preparation of a fulminating compound from silver. The substance that explodes most easily, is prepared by the action of ammonia. For this purpose, lime water is added to the nitrate, and the precipitate, after being washed and dried, is put into a glass cup with aqua ammoniæ, and in the course of ten or twelve hours it becomes black. The fluid is then to be poured off, and the powder dried cautiously by *exposure to air.*

This substance explodes easily by the slightest friction or percussion. It ought not, therefore, to be removed from the vessel in which it is prepared, and of course very little, not more than a grain, should be made in each.

Another detonating compound, discovered by Brugnatelli, is obtained from the nitrate by the action of alcohol. For preparing it, 50 grains of lunar caustic in powder are thrown, in small quantities at a time, into an ounce of a mixture composed of equal parts of nitric acid and spirit of wine, of specific gravity 860. An action commences, accompanied with the disengagement of red fumes, during which a white powder is deposited; and when this has taken place, water must be poured on to

put a stop to it. It may be also procured, by dissolving 30 grains of pure silver in an ounce of diluted acid, (equal measures acid and water,) and adding, after the solution is completed, 2 ounces of alcohol. By the application of a very slight heat, the powder is deposited; but the moment it appears, more spirit of wine must be put in, to prevent the action from becoming too violent. The powder thus formed, must be collected on a filter, and dried by *exposure to air*.

When a little of the detonating silver is put into paper, and struck with a hammer, or rubbed in a mortar, it explodes with great violence. Hence its use in making *detonating balls* and *pullaways*. The former are prepared by wrapping about 1-4th of a grain, into a piece of very fine paper, with a dried pea. This, when thrown on the floor, is instantly exploded. The latter are formed, by putting a little of the powder with sand between two pieces of thick paper, and securing these together, by pasting another piece of paper round that part containing the powder. When drawn asunder, the friction is sufficient to cause explosion.

Detonating silver is exploded also when touched with sulphuric acid.

Fulminating silver, according to the experiments of Leibig, contains oxid of silver in union with an acid, having cyanogen and oxigen; for when heated with oxid of copper, carbonic acid and nitrogen, in the same proportion as generated by the combustion of cyanogen, were disengaged. But besides these, it seems to contain also silver as one of its ingredients. When treated with solution of potassa, or of its muriate, the acid and alkali combine; indeed, the acid may be transferred to any base. The compounds thus formed, detonate, but not so powerfully as that of silver. (An. of Ph. N. S. vii.)

It has been mentioned, (vol. i. p. 326.) that though the acid of fulminating silver can be transferred to other bases, it cannot be got from them. In a late paper, however, by Leibig, (An. de. Ch. et de Ph. xxxiii.)

he has pointed out a method, by which he asserts that he has succeeded in obtaining the acid. It consists in transmitting a stream of sulphuretted hydrogen through water, holding fulminating silver suspended in it, but ceasing before the whole of the fulminate is decomposed. Sulphuret of sulphur is then deposited, and fulminic acid, according to Leibig, left in solution. It reddens vegetable blues, has an acid taste, and neutralizes salifiable bases. If the stream of gas be continued till the whole of the fulminate disappears, the acid, though set at liberty, is decomposed, and other products are formed, the nature of which has not been ascertained.

Alloys.

Silver unites with almost all the metals. The most important alloy is that with copper, forming *Standard* or *Sterling Silver*, which is composed of 12¾ silver, and 1 copper. It is much harder than the pure metal, and is therefore better adapted for coins and trinkets.

Silver unites also with gold. It has been mentioned, that the latter is frequently alloyed with the former, for making jewellers' gold. As this alloy is more easily fused than sterling gold, it is used for soldering it.

Silver is used as a medium of exchange, and for trinkets and plate. It is employed also for giving a coating to other metals, with the view of making them appear like it; or for enabling them to be put to purposes, to which they could not otherwise be applied. The only metals that are silvered, are copper, or brass, and pewter; the process differing according to the thickness of the coating required. An easy method of silvering is by the amalgam. For this, silver in powder, prepared from the nitrate by copper, as already described, is mixed with four times its weight of common salt, four of sal ammoniac, and a fourth part of corrosive sublimate, and made into a paste with water, with which the surface of the metal is covered, till the whole of it acquires a white metallic coating. This is an amalgam of the silver and the mercury of the sublimate, from which

the latter is expelled by heating it, and the former is left adhering to the metal. Another mode of silvering is by *luna cornea*. This is mixed with three of pearl ash, one of whiting, and one of sea salt, and sprinkled on the metal, previously heated, which gradually acquires a coating of silver; but as it is very thin, it requires to be varnished, to prevent it from being rubbed off. A more durable kind of silvering is given, by putting on a bar of copper, another of silver, of about 1-12th part of the thickness, with a little powdered borax between them. By exposing this to heat, the borax is melted, and causes them to unite; so that, by passing them between rollers, they can be extended to plates, the silver always bearing the same proportion to the copper which it did at first.

Methods of Procuring Gold and Silver.

Gold is always found in its metallic state, alloyed with silver and copper. Some iron and lead ores also contain a sufficient quantity of it to make them valuable as ores of gold. When gold is alloyed with silver, mixed with stony matter, the method of extracting it is very simple. The ore is first broken into pieces, and freed as much as possible from impurities, after which they are reduced to powder, and made into a paste with salt and water. Mercury is next squeezed through a leather bag on the mixture, and as it flows in, in very minute globules, it is mixed intimately with the ore. When the proper quantity is added, the whole is beat well together, and kept at about the temperature of boiling water for some days, till the union is effected, after which the earthy matter is washed away, and the residue is subjected to distillation, by which the mercury is expelled, and the gold containing a little silver is left. These are easily separated by the process of *parting*. For this purpose the metal, being extended to thin plates, is put into diluted nitrous acid, by which the silver is dissolved, and the gold left, the former only being soluble. From the solution the silver can be precipitated by the immersion of a piece of copper.

In those cases in which the gold is alloyed with other metals, the process for procuring it is more complicated. The ore is first roasted, to drive off sulphur, and then heated along with lime and lead ore, and when completely fused, it is drawn off into moulds. The metallic matter thus obtained, after being repeatedly fused, is an alloy of gold, silver, lead, and copper, from the two last of which it is separated by the process of *cupellation*. Gold and silver are not oxidated by heat and air, while the others very quickly pass into the state of oxid when heated. On this depends the process of cupellation, which is merely the separation of gold and silver from other metals, by means of oxidation, as will be immediately described.

Silver is obtained, not only from the ores of this metal, but also from those of lead; some of which afford a sufficient quantity to make it of importance to extract it from them. Two modes are followed, *amalgamation* and *fusion*. The first is performed, by mixing the ore with sea salt, and heating it till the vapours cease to come off. When the product is cool, it is reduced to powder, amalgamated, and then heated, by which the mercury is driven off, and the silver left, but still alloyed with copper. In conducting the process of fusion, the ore, which is generally one of lead, is roasted, to expel the sulphur, and is then heated along with charcoal, by which the lead is reduced and melted, and falls to the bottom of the furnace, carrying the silver with it. From the products thus obtained, the silver is procured by cupellation. The vessel or *cupel* in which the refining is carried on, is made of bone ashes. It is placed in a furnace, and when properly heated, the alloy is put in, and a stream of air allowed to pass over it, by which the oxidable metals are oxidated, and absorbed by the dish, while the silver is left in its metallic state. If not pure, the process must be repeated.

In freeing gold from other metals, recourse is often had to cupellation, which is conducted in the same way

as with silver; but as the alloying metals are in small quantity, it is in general necessary to add some lead, which, during the process, is oxidated, and absorbed by the dish, carrying with it the whole of the impurities. Should the gold still contain silver, they are separated by *parting*, as already described, (Aiken's Chem. Dict.)

PLATINUM.

Platinum was not known in Europe till about the middle of the last century, when it was brought here by Mr Wood, Assay Master at Jamaica, who, in 1749, gave an account of some of its properties.

It is found chiefly in South America, in small flat grains, but which are not the metal in its pure state; they contain no less than four others, that have not been found any where else, and one or two more, frequently met with.

When pure, it is of a white colour, somewhat resembling silver, though rather darker, and having less lustre. Its sp. gr. is 2150; its atomic weight 120. In hardness it is inferior to few, if any, of the metals. It is possessed of great malleability and ductility. It may be beat into very fine leaves, and drawn to wire, not exceeding 1-2000th part of an inch in thickness. When about the 1-13th of an inch thick, it sustains a weight of 270 lbs.

Platinum requires a higher heat than any other metal for its fusion, that of a blast furnace not being sufficient to melt it; it may, however, be fused by the oxi-hydrogen blow-pipe. When heated to whiteness, like iron, it can be *welded*, and hence a method of getting it in its malleable state.

It expands very little by the application of caloric. According to Wollaston, if we consider the expansion of steel, between the freezing and boiling points of water, as 12, that of platinum is only 9. He states

also, that it is a worse conductor than any of the other metals, its conducting power being to that of copper as 1 to $2\frac{1}{3}$, and to silver as 1 to $3\frac{1}{3}$.

Platinum is not oxidated by heat and air. It can, however, be converted to an oxid by electricity, and by the oxi-hydrogen blow-pipe.

Oxids.

It unites with two proportions of oxigen, forming protoxid and peroxid, the former of which only has been obtained in its uncombined state.

According to Berzelius, the protoxid may be procured by the addition of potassa, in excess, to a solution of the metal in nitro-muriatic acid, by which a black powder is precipitated. It contains, according to him,

metal, 100 = 1 atom 120
oxigen, 8.28 = 1 atom 10.

When exposed to a strong heat it is decomposed, the whole of its oxigen being expelled, and the metal left pure.

Peroxid, though not yet obtained except in a state of combination, is, according to Berzelius, composed of

metal, 100 = 1 atom 120
oxigen, 16.38 = 2 atoms 20.

Another compound of platinum and oxigen has been mentioned by Mr Davy, and which, he says, consists of

metal, 100 = 2 atoms
oxigen, 11.86 = 3 atoms.

He procured it by boiling nitric acid and fulminating platinum, drying the residue, heating it, and then washing it with potassa.

Muriate.

Platinum resembles gold in its power of resisting the action of acids. The only one that acts on it is the nitro-muriatic. For dissolving it 3 of muriatic and 1 of nitric should be employed, the metal being previously cut into

small pieces, and the heat continued till the whole of it is dissolved. The action goes on with the usual appearances, and a brown solution is obtained, that yields crystals of the same colour, and which may be considered a muriate, or a chlorid. The alkalies decompose the muriate; but the phenomena differ according to the substance employed.

When potassa is added to the solution, a brown precipitate falls, which is a compound of the alkali and the muriate, *muriate of platinum and potassa*, or, according to some, a *chlorid* of *platinum* and of *potassium*, in the proportion, according to Thomson, (First Pr.), of

3 atoms chlorine,	135
1 atom platinum,	120
1 atom potassium,	50,

which, from analysis, he finds are so combined as to form

1 atom bi-chlorid of platinum,	210
1 atom chlorid of potassium, -	95.

When soda is added to the solution of the muriate, there is no precipitation, but it enters into union, and forms a similar compound, either a *muriate of platinum and of soda*, or a *chlorid of platinum and of sodium*. It may also be procured by boiling the metal in a mixture of nitric acid and sea salt, and evaporating the solution till it begins to deposit crystals. It is composed, according to Thomson, of

bi-per-muriate of platinum,	1 atom
muriate of soda, -	1 atom
water, - -	5 atoms;
or, bi-chlorid of platinum,	1 atom
chlorid of sodium, -	1 atom
water, - -	8 atoms,

3 of the atoms of water being, in the first case, consumed in the acidification of the chlorine, and oxidation of the metals.

The action between the muriate and ammonia, or its muriate, is also important. When a solution of sal-ammoniac is added to it, a precipitate falls, which must be

considered a triple compound, a *muriate of platinum and ammonia;* or, according to Thomson, of *chlorid of platinum and ammonia*, in the proportion of

bi-chlorid of platinum,	1 atom
muriate of ammonia,	1 atom.

When this is exposed to a red heat, it is decomposed, muriate of ammonia and chlorine being disengaged, and platinum, in its *spongy state*, obtained; and hence the method of procuring spongy platinum for the hydro-pneumatic lamp. For this purpose, having dissolved the metal in nitro-muriatic acid, composed of 3 of muriatic and 1 of nitric acid, by the application of heat, sal ammoniac must be added as long as it occasions precipitation. The mixture is then to be thrown on a filter, washed with a little water, and dried; after which it is to be exposed to a red heat, in a crucible, for about a quarter of an hour. It ought then to be removed cautiously, without compressing it, and kept in a box excluded from the air, to prevent it absorbing moisture and dust. If the platinum, *in grains*, has been used, the sponge should be dissolved a second time in acid, and precipitated by the sal ammoniac, so as to get it pure; but if the plate platinum has been employed, there is no necessity for the second solution.

Muriate of platinum is decomposed by some of the metallic salts. When green sulphate of iron is boiled with it, platinum in its metallic state is precipitated, owing to the iron depriving it of its oxigen.

The action with proto-muriate of tin is peculiar. When the solution, recently prepared, is added to the muriate, a red precipitate is formed. If the muriate of platinum be so much diluted as scarcely to tinge the water, it becomes red on the admixture with the proto-muriate; and hence the use of the latter as a test of the former. Hydr-iodic acid tinges the solution of the muriate of the same colour, and hence also its use as a test of platinum.

Fulminating Platinum.

When a stream of sulphuretted hydrogen gas is passed through the solution of the muriate, a dark-coloured *sulphuret* is precipitated, which, when boiled in nitric acid, becomes sulphate, owing to the acidification of the sulphur, and oxidation of the metal. From this solution, *fulminating platinum* can be obtained, by the addition of ammonia in excess, washing the precipitate, and boiling it in solution of potassa nearly to dryness. The residue, after being washed, is then dried by a slight heat.

As thus formed, it is a dark-coloured powder, which detonates with considerable violence at the temperature of about 420. It explodes also by friction, but not by percussion. Like the other fulminating compounds prepared in the same way, it is supposed to be a compound of oxid of platinum, ammonia, and water.

When equal measures of strong solution of platinum and alcohol are boiled together, a dark-coloured powder is gradually deposited, which, after being washed, and dried by a gentle heat, is possessed of remarkable properties. When heated, it explodes with a hissing noise, and a bright flash of red light, leaving platinum in its metallic state. When introduced into ammoniacal gas, it becomes red-hot, and hence it has been proposed to employ it as a means of affording a light, but which of course is superseded by the more easy application of hydrogen to spongy platinum. It is decomposed by alcohol, which, almost the moment it touches it, makes it red hot. If, for instance, a little of it be put on paper wet with alcohol, ignition immediately follows. According to the experiments of Mr Davy, (Ph. Tr. 1820.) it is composed, in the 100 parts, of 96.5 of platinum, the remainder being nitrous acid, oxigen, and carbon; so that it is probably similar in its composition to fulminating silver, containing platinum in union with some compounds of cyanogen.

Alloys.

Platinum unites with almost all the metals, but the alloys are not put to any particular use. The union between it and tin, lead, or antimony, is easily effected, the action being accompanied with the evolution of heat. When, for instance, a piece of sheet lead and of platinum foil are put together, and heated at the edge by a blowpipe, they suddenly unite with explosion, the alloy becoming fluid and scattered about, and emitting much heat and light. The same occurs with tin, zinc, or antimony, when surrounded by platinum foil, and treated in the same way.

Platinum unites easily with gold. When it was first introduced to this country, the importation of it into Spain was prohibited, from an idea, that as it is of great weight, it might be used to adulterate gold,—a prohibition which was unnecessary, for the addition of about 1-40th impairs its properties so much, that it is easily detected.

Platinum is found in few places. It is got in Choco in Peru, and in Santa Fé, near Carthagena; and Vauquelin has lately discovered it in the silver mines of Gaudalcanal in Estremadura. It has been found also in St Domingo and in the Brazils.

Platinum is obtained in different ways from the grains. One method is, by dissolving them in aqua regia, and decomposing the solution by sal ammoniac, by which the spongy metal is procured; and to get this in a malleable state, it is put into an iron mould, and compressed by means of a strong screw, after which it is heated to redness, and repeatedly hammered, till it yields a uniform mass. It is also obtained in its malleable state, by mixing the sponge with mercury, and subjecting it to heat, by which the mercury is driven off. A number of pieces thus formed, are then put together, and welded.

Platinum, from its infusibility, and its power of resisting the action of chemical agents, is well adapted for

chemical apparatus, as crucibles and evaporating dishes, though the difficulty of working it makes it very expensive. On a larger scale, it is made into retorts in which sulphuric acid is boiled, after it is drawn off from the leaden chambers in which it is prepared. Instead of pure platinum, copper utensils coated with it are sometimes employed, by which the expense is considerably diminished. The coating is done in the same way as with silver, by covering the copper with an amalgam, prepared by mixing mercury with spongy platinum, and heating it, by which the former is driven off, and the latter left adhering to it.

Platinum is also used in painting on porcelain. For this purpose, the sponge is mixed with a flux, and put on the ware, which is afterwards heated. In the same way, earthen-ware vessels are often covered with platinum, by which they receive a resplendent coating, and thus become bad radiators, so that they are rendered better for retaining heat, (vol. i. p. 45.)

OSMIUM, IRIDIUM.

When nitro-muriatic acid is boiled on platinum grains, a black shining powder is left, which has been found to consist of two metals, the one called *iridium*, from the different colours of its compounds, the other *osmium*, from the pungent odour of its oxid, (*οσμη*, *odor*.)

To separate these, the powder is digested alternately in soda and in muriatic acid, till the whole of it is dissolved, the solutions being kept separate. The former contains the osmium, the latter the iridium.

Osmium.

When sulphuric acid is added to the alkaline solution, it unites with the potassa, and oxid of osmium is separated, and by distillation is obtained pure, being easily

converted to vapour, which can be condensed in a cold receiver. When the fluid thus procured is agitated with mercury, an amalgam is formed and precipitated, from which the mercury can be expelled by heat; and if the process be conducted in close vessels, the osmium is left in its metallic state.

It is of a dark steel grey colour. It does not fuse by a strong heat excluded from air; but when it is present, it is oxidated and evaporated. The solution of the oxid in water is colourless, having a sweet taste, but a pungent disagreeable odour; and hence the origin of the name.

It stains the skin of a dark colour.

Osmium does not seem capable of uniting with acids.

Iridium.

When the muriatic solution of the powder is crystallized by evaporation, and the crystals, after again dissolving them, are exposed to heat, the acid and oxigen are expelled, and the metal is left pure. It is, according to Children, a white brilliant metal, of sp. gr. 1860. Its muriatic solution is decomposed by all metals, except gold and platinum, by which iridium is deposited.

Ammonia precipitates part of the oxid, retaining the remainder in solution.

Dr Thomson, from the decomposition of the muriate, infers that the atomic weight of iridium is 37.5.

RHODIUM AND PALLADIUM.

These two metals were discovered by Wollaston in the nitro-muriatic solution of platinum, (Ph. Tr. 1805.) and may be obtained by the following process:—After precipitating the platinum by sal ammoniac, immerse a plate of zinc, and a black powder is deposited, which, by digestion in nitric acid, yields copper and lead. Treat the residue with nitro-muriatic acid, and to the solution

add muriate of soda, equal in weight to a fifth part of the platinum grains employed, and then evaporate. The residue consists of muriates of soda, platinum, palladium, and rhodium, the two first of which, when it is washed with alcohol, are removed, and by dissolving the remainder in water, a solution is obtained, which, by the immersion of a piece of zinc, affords a black precipitate. When this is heated with borax, it becomes white, with a metallic lustre. It is rhodium in a state of purity.

Rhodium

Is of sp. gr. 1100. Its atomic weight is 55. It requires the heat of a blast furnace for its fusion. By alloying it with other metals, as with lead, it may be dissolved in nitro-muriatic acid, and it then yields a red-coloured solution; and hence the origin of its name, (ῥοδον, *rosa.*)

Palladium.

The alcohol employed in carrying off the other substances from rhodium, contains palladium in union with muriatic acid and soda, from which it can be obtained by the addition of ferro-cyanate of potass; but an easier mode of procuring it is, to add to muriate of platinum, after removing the platinum by sal ammoniac, a solution of hydro-cyanate of mercury, by which a precipitate is thrown down, and which, by the application of heat, yields palladium pure.

The muriate is decomposed by the alkalies, which throw down a yellow precipitate. It is not affected by muriate of ammonia, or by hydro-sulphurets.

Palladium is of a colour somewhat similar to that of platinum. Its sp. gr. is about 1100; its atomic weight 70. It is malleable and ductile. It requires a higher temperature than gold for its fusion.

Nitric and sulphuric acid dissolve it, but the readiest solvent is nitro-muriatic acid, which affords a rich red-

coloured solution of the muriate, easily decomposed by the alkalies and earths. Sulphate, nitrate, and muriate of potass, also throw down precipitates. Green sulphate of iron precipitates palladium in its metallic state. Proto-muriate of tin forms a dark orange precipitate, and hence its use as a test of palladium.

Palladium unites with other metals.

Like platinum, it destroys the colour of gold, a sixth part being sufficient to make it quite white.

For the other methods of procuring these four metals, see London Journal, xii.

BISMUTH.

Bismuth was known as a distinct metal about the beginning of the 16th century, but no accurate account was given of it till 1763, when Geoffery detailed a few of its properties, since which it has been examined by Lagerhjelm, and Dr Davy.

It is of a whitish colour, with a slight tinge of red. It has a foliated texture, and in hardness is between copper and lead. Its sp. gr. 9820. Its atomic weight is 90. When cautiously hammered its density is increased, but it is not malleable or ductile, being easily broken by a smart blow. A rod of 1-10th of an inch in thickness, sustains a weight only of about 30 lb. Its fusing point is very low, but it has been differently stated by authors. It is, according to Berzelius, 451.5; Lewis, 460; Irvine, 476; the last of which is considered the most correct. If, after fusion, it is allowed to cool slowly, it crystallizes perhaps more easily than any other metal.

Oxid.

When heated in contact with air, it acquires a brownish crust on its surface, and, by agitation, the whole of it is converted into a brownish powder. If the temperature be high, it takes fire, and burns with a blue flame,

forming a yellow oxid, which at a very high heat is fused, and becomes a yellow glass.

Only one compound of bismuth and oxigen is known. It is, according to the experiments of Dr Davy, composed of

metal, 100 = 1 atom 90
oxigen, 11.11 = 1 atom 10.

The acids in general act easily with bismuth, and form colourless salts, many of which are decomposed by water.

Nitrate.

The action between nitric acid and bismuth, is similar to that with tin. When the strong acid is used, a great deal of nitric oxid is disengaged, and a white powder is formed, consisting chiefly of oxid. To obtain a solution, it is necessary to moderate the action by dilution with water, by which the bismuth is oxidated, and then unites with the remainder of the acid. The fluid is transparent and colourless, and, by evaporation, yields transparent crystals. When it is thrown into water, there is an immediate decomposition and precipitation of a white powder, which is a *hydrated oxid*, probably retaining a little of the acid. It was long known by the name of *magistery of bismuth*, and is now employed in medicine, as a tonic.

Nitrate of bismuth is decomposed also by the alkalies, and some of their salts. The action with a hydro-sulphuret is important as affording a very good sympathetic ink. On the addition of any hydro-sulphuret to the solution, a black precipitate is formed; hence, when characters are drawn on paper with the nitrate, they are invisible, but when exposed to sulphuretted hydrogen gas, or immersed in a weak solution of hydro-sulphuret, they instantly become black.

The other salts of bismuth present nothing interesting.

Alloys.

Bismuth combines with most of the metals, and forms

alloys which are in general brittle, and fusible at a low temperature; and hence its use in communicating fusibility to other metals, as in forming solders, a little of it being sometimes mixed with the tin and lead employed for this purpose; and it is used also in making some kinds of pewter. When it is mixed in large quantity with tin and lead, the alloy is so fusible that it is melted when thrown into boiling water; and if to this a little mercury be added, the fusing point is still farther reduced; hence the use of these materials in making *fusible metal*, prepared by fusing together 9 of bismuth, 5 of lead, and 3 of tin, and then adding 2 of mercury. The fusing point of this alloy is about 150. Hence a spoon made of it, when put into soap or tea, instantly disappears, the temperature being sufficient to melt it, and thus exciting a little surprise in the person who uses it.

Bismuth is occasionally found native, but it usually occurs in union with oxigen or sulphur, from which it is always obtained. For this purpose, the ore is first roasted, generally along with fuel, in shallow pits dug in the earth. The metallic matter collected at the bottom is then put into a crucible, with charcoal, and covered with sea salt; heat is applied for a short time, by which the mixture is fused, and the bismuth falls to the bottom, the charcoal having deprived it of its oxigen, and allowed it to assume the metallic state. It is not, however, pure, it contains a little lead, and sometimes silver; but it is sufficiently so for the purposes to which it is usually applied. When required pure, it is prepared from the oxid thrown down from the nitrate by water, by washing it and exposing it to heat in a crucible, along with charcoal.

COBALT.

A MINERAL called *cobalt*, has been long in use for giving a blue colour to glass, which has been found to contain a peculiar metal, possessed of remarkable properties.

When pure, it is of a pale reddish colour; is soft and brittle, so that it is easily reduced to powder. Its texture differs according to the mode of preparing it, being sometimes foliated, at other times granular. Its sp. gr. is 8300. Its atomic weight 32.5. Even when pure it is said to be magnetic, and may itself be made into a magnet. This property of cobalt is supposed, however, by some, to be owing to the presence of iron; but Tassaert asserts, that it continued to be obedient to a magnet, after means had been taken to remove all impurities, and when the tests could not detect the smallest quantity of iron in it.

Cobalt requires a very high temperature for its fusion, 130 of Wedgewood being necessary. When cooled slowly, it assumes a crystalline form.

When heated in contact with air, it forms an oxid, which is at first pale blue, but gradually becomes darker, till at last it appears black. If the temperature to which it is exposed is high, it burns with a reddish flame.

Oxids.

Cobalt unites with two proportions of oxigen. When to a solution of one of its salts, potassa is added, a bluish precipitate is formed, which is the protoxid, composed, according to Thomson, of

metal,	100	1 atom,	32.5
oxigen,	30	1 atom,	10.

On exposing this to air, particularly during the process of drying, it absorbs oxigen, and becomes of a deep blue colour, indeed so intense as to appear black.

This is the peroxid, composed, according to the same authority, of

metal,	100	1 atom, or	2
oxigen,	45	$1\frac{1}{2}$ atom,	3.

The protoxid is soluble in acids, giving, in general, reddish-coloured solutions. The peroxid, when acted on by them, is decomposed, losing a part of its oxigen, and being reduced to the state of protoxid. When muriatic acid is employed, a solution of the proto-muriate is ob-

tained, and chlorine is disengaged, the oxigen liberated having combined with the hydrogen of part of the acid; so that the action is similar to that of the black oxid of manganese. The peroxid seems, therefore, incapable of uniting with acids.

The peroxid is also decomposed by heat, air being excluded, by which about 10 per cent. of oxigen is disengaged, and protoxid left.

Cobalt is easily dissolved by the acids, and forms salts possessed of sympathetic properties. Though these may be formed by the action of the acids on the metal, it is seldom employed for this purpose, the oxids of commerce being generally used. The most important of the salts is the muriate.

Muriate.

This may be prepared by dissolving the metal in nitro-muriatic acid, or the impure oxid, called *zaffre*, in muriatic acid, by the application of a slight heat. The solution, when concentrated, is of deep red colour, which becomes paler by dilution. If a sufficient quantity of water be added to make it colourless, it then forms a very fine sympathetic ink.

Traces drawn with it on paper are invisible, but when *slightly heated*, become blue. As the paper cools, the traces disappear, and the more moist the atmosphere, the more rapid the change. They may be again restored, merely by heat, and these changes may be effected any number of times, provided care is taken not to injure the texture of the paper. If the solution of cobalt be mixed with other substances, different colours may be imparted. Thus, if a little gamboge be added, it gives yellow traces, but which, when dried, become green, this being produced by the yellow of the gamboge and blue of the cobalt. If mixed with lake, they become purplish when heated, the red and blue yielding purple. Amusing experiments may therefore be performed with these solutions. Thus, when we

wish to make a landscape change its appearance, say from a winter to a summer scene, the trunks of the trees are coloured brownish, while the leaves and fore-ground are covered with the cobalt solution, to which a very little gamboge is added, but not so much as to give it colour. On heating the paper, the leaves and fore ground become green, and thus change the landscape from winter to summer.

If the solution of cobalt contain other metals, and which is frequently the case, the colour of the traces, when dry, is not blue. If copper or nickel be present, they become green; and the last mentioned metal very frequently exists in cobalt ores, and remains with it in zaffre. It is necessary, therefore, if we wish a pure sympathetic ink, to remove the foreign metals. *(See Nickel.)* The muriatic solution of zaffre, however, when it contains nickel, answers for the traces becoming green, so that there is no necessity for the addition of gamboge.

Cobalt unites with other metals, but the alloys present nothing interesting.

Cobalt is found in union with other metals. It has been detected in meteoric stones; but the principal ore is that with arsenic and sulphur, and from which it is usually obtained. In the different processes to which the ore is subjected, substances employed in the arts, under the names of *zaffre* and *smalt*, are formed, and from which the metal itself may be procured.

To prepare zaffre, cobalt ore, containing arsenic and other impurities, is exposed to heat, during which a considerable quantity of vapour is given off. When these have ceased, it is removed, powdered, and a second time heated, after which it is again reduced to powder, and mixed with that of flints.

Smalt is procured by roasting zaffre with potashes for 12 hours, and pouring it, when fluid, into water, by which it is afterwards more easily reduced to powder. It may also be obtained, by exposing to a strong heat, a mixture of cobalt ore, flints, and potashes, by which the previous preparation of zaffre is avoided. When

properly formed, it is a blue vitreous substance, hence sometimes called *azure blue*. It is used for giving colour to glass and porcelain. When mixed in very small quantity with the former, it makes it of a deep blue, 4 or 5 grains being sufficient to colour an ounce. It has the advantage of not being destroyed by heat, a property not possessed by other substances used for the same purposes. Smalt, when mixed with starch, forms *blue*, used in washing linens, to prevent them from becoming yellow.

Cobalt, in its metallic state, may be obtained sufficiently pure for most of the purposes to which it is applied, by heating zaffre with three parts of black flux (burned cream of tartar) in a crucible, till fumes cease to come off. When required free from the metallic impurities always existing in the ore from which zaffre is prepared, the muriate is decomposed by the salt called oxalate of ammonia, by which a reddish precipitate of oxalate of cobalt is formed. When this is heated with black flux, it yields the metal pure.

NICKEL.

The ore called *kupfernickel*, found in different parts of Germany, was for a long time considered to belong to the copper family; but Cronstadt, in 1751, asserted that it contained a peculiar metal, to which he gave the name of nickel; an assertion at first disbelieved, but afterwards proved by the experiments of Bergman.

Nickel, when pure, resembles silver in appearance. It is possessed of considerable malleability, and may be beat into plates of 1-100th part of an inch in thickness. Like iron, it is obedient to a magnet, and may itself be made magnetic, even though the most delicate tests cannot detect the slightest trace of iron in it.

Its sp. gr. is from 8400 to 8932. Its atomic weight 32.5.

It requires a very high temperature for its fusion, the fusing point being above that of iron, and therefore at least 160 of W.

It is not altered by exposure to air, but when heated in contact with it, it undergoes various changes in colour. It at first becomes light yellow, then deep yellow, next of a violet colour, and lastly blue. It is difficult, however, to oxidate it completely in this way.

Oxids.

Nickel unites with two proportions of oxigen, but very different statements have been given of the composition of the oxids. From the experiments of Proust, Tupputi, Richter, and others, the protoxid seems to be composed of 100 of metal to 27 of oxigen; while Dr Thomson makes it

metal,	100	1 atom	32.5
oxigen,	30	1 atom	10

This oxid may be prepared by the addition of an alkali to the solution of nickel in nitric acid.

The other oxid may be obtained by passing chlorine gas through water, holding the protoxid suspended in it, by which the chlorine, uniting with the hydrogen of the fluid, imparts more oxigen to the oxid, and converts it to peroxid. It appears to be a compound, containing once and a half as much oxigen as the protoxid; but the experiments from which this conclusion is drawn, are by no means satisfactory.

Like many of the metals in a high state of oxidation, it is converted to protoxid by the action of acids. Thus sulphuric acid disengages part of its oxigen, and forms proto-sulphate, while with muriatic acid it liberates chlorine, so that it does not seem to form salts. Its action with ammonia is also peculiar. When thrown into its solution, there is a copious disengagement of nitrogen, owing to the excess of oxigen uniting with its hydrogen.

Most of the acids act on nickel, and form salts of a beautiful green colour.

Nitrate.

This may be formed by the solution of the metal in diluted nitric acid. It is of a rich green colour, and affords crystals by evaporation. On the addition of the alkalies and their carbonates, the oxid or carbonate may be precipitated. The action with ammonia is peculiar. When added to the solution, a bluish powder is thrown down, which changes in the course of a short time to red, and afterwards to violet. On adding the alkali in excess, the precipitate disappears, and hence the method of separating nickel from many other metals. It is evident, however, that it cannot be separated in this way from copper, for the oxid of it is also soluble in ammonia. This is, however, easily done by bringing the ammoniacal solution back to the state of a salt, by the addition of nitric acid, and then transmitting a stream of sulphuretted hydrogen through it, by which the copper only is deposited in the state of sulphuret, so that nitrate of nickel is left in solution.

Ferro-Cyanate.

Ferro-cyanate of nickel is of a greenish colour. It may be formed by the addition of ferro-cyanate of potass to the nitrate; and hence the use of this salt as a test of nickel, for by adding ammonia in excess, filtering, adding an acid, and then the ferro-cyanate, the green precipitate appears, if nickel is present.

Nickel unites with other metals, but the alloys present nothing interesting.

Nickel is obtained by a very tedious process, from the ore commonly called *speiss*, containing chiefly nickel and arsenic. For this purpose it is dissolved in a mixture of nitric and sulphuric acid, by the aid of heat, by which sulphate and arsenate of nickel are formed, and held in solution. On evaporation, crystals of the former are deposited, and by passing a stream of sulphuretted hydrogen through the mother liquor, to throw down the arsenic, more sulphate will be obtained by farther evapora-

tion. These, when dissolved in water, and mixed with carbonate of soda, afford a carbonate which is easily decomposed, by mixing it with oil, placing it in charcoal, and exposing to a red heat, (An. Ph. xiv.)

The nitrate, when exposed to the oxi-hydrogen blowpipe, also yields nickel.

Nickel has been found in all the different specimens of native iron yet analyzed, and it has been detected in the different varieties of meteoric stones; a strong proof, as some suppose, that the former are also of the same origin. The quantity varies from about 2 to 17 per cent. It exists also in the *white copper* brought from China, in union with copper, iron, and zinc, and which is supposed to be obtained from a native production called white copper ore. The composition of the white copper, I have found to be copper 40.4, zinc 25.4, iron 2.0, and nickel 31.6, (Ed. Ph. Journ. vii.)

CADMIUM.

Cadmium was discovered by Stromeyer in 1817, in an ore of zinc, which, from its becoming yellow when heated, was supposed to contain iron. He has since found it in other ores of zinc, and it has been procured by Dr Clarke, and Mr Herapath, from those found in this country.

Cadmium is of a light grey colour, resembling tin in appearance. It has considerable brilliancy, and takes on a fine polish. It is of a compact texture, and is possessed of malleability and ductility. Its sp. gr. is 8600. Its atomic weight 70.

It is fused at comparatively a low temperature, and at about the boiling point of mercury, passes off in vapour, which condenses unchanged in its properties in the cool part of the apparatus.

Oxid.

When heated in contact with air, it is inflamed, and forms a brownish yellow oxid, composed of

metal,	100	1 atom	70
oxigen,	14.35	1 atom	10

It does not suffer any change by exposure to an intense heat. When heated with charcoal it is decomposed, and the metal when reduced is volatilized.

It is soluble in ammonia, but not in the fixed alkalies; and as the latter dissolve oxid of zinc, hence a method of separating them when they exist in union with an acid.

Salts.

Cadmium is dissolved by the acids, and forms colourless salts, which are decomposed by the fixed alkalies; and hence a method of procuring the oxid. As thus precipitated, it is white, owing to the presence of water. Ammonia in excess precipitates it, and then re-dissolves it. Sulphuretted hydrogen produces a change similar to that upon arsenical compounds, throwing down a yellow precipitate resembling orpiment. Ferro-cyanate of potass causes the deposition of a white powder.

Cadmium is precipitated from its salts in its metallic state by zinc, and during its evaporation assumes a dendritic appearance. On the contrary, when a piece of cadmium is put into a solution of a salt of gold, silver, copper, or lead, they are deposited by the cadmium depriving them of their oxigen.

Alloys.

Cadmium unites with other metals, and forms brittle alloys, but there is no danger whatever of the compounds retaining this property, because, when sufficiently heated, they give off the whole of the cadmium. Hence, though brass is frequently made by exposing zinc ore to heat with copper and charcoal, it does not contain cadmium;

indeed 1-100th part of it, if present, would deprive it completely of malleability and ductility.

Cadmium is obtained by dissolving the ore in sulphuric acid, precipitating by sulphuretted hydrogen, dissolving the product in muriatic acid, and adding carbonate of ammonia; carbonate of cadmium is deposited, and from which the metal can be obtained in the usual way of reduction by charcoal.

CERIUM.

A Swedish mineral, considered an ore of *Tungsten*, was by Berzelius found to contain a peculiar metal, to which he gave the name of *Cerium;* the planet Ceres having been discovered a short time before. It has since been detected by other chemists, particularly in the mineral called *Allanite*, found in Greenland.

We are not acquainted with the properties of cerium in its metallic state, having been as yet obtained in very minute quantity. Its oxids are procured from the ores in which the metal has been detected. When treated with nitro-muriatic acid, and after neutralizing the excess of acid, adding oxalate of ammonia to the solution, a white precipitate is produced, which, when exposed for some time to heat and air, absorbs oxigen, and becomes per-oxid of a reddish colour.

Salts.

The oxids of cerium are soluble in acids, forming salts having a sweetish taste, and easily decomposed by the alkalies.

The nitrate, on exposure to heat, leaves the red oxid.

The sulphate of the protoxid has a slight reddish tinge; the per-sulphate is yellow.

The muriate, when evaporated to dryness, and heated, burns with a yellowish flame. These salts are not decomposed by sulphuretted hydrogen.

URANIUM.

Uranium was discovered by Vauquelin in the mineral called *Pitchblende*, in which it exists along with other metals. The process given by Thomson (First Pr.) for procuring it, consists in digesting the mineral in nitric acid, and after boiling to drive off excess of acid, precipitating the foreign metals by sulphuretted hydrogen. The solution, when filtered and boiled, is then mixed with ammonia, and the precipitate, after being washed, is digested in a strong solution of carbonate of ammonia; a fluid is thus obtained, which yields yellow crystals of carbonate of ammonia and of uranium. On exposing these to a red heat, oxid of uranium is procured; and by passing a stream of hydrogen over it, the oxigen is abstracted, and the metal left pure.

Uranium is, according to Arfwedson, (Stock. Acad. of Sciences, 1822,) of a liver-colour, not altered by exposure to air, but when heated in contact with it, takes fire, and becomes oxid.

It unites with two proportions of oxigen, forming a green or protoxid, and a peroxid, which seems to have acid properties. The first of these is obtained by the process of Thomson, already described, but the last has not yet been procured uncombined.

Salts.

The salts of uranium contain both of the oxids, but it is difficult to procure a pure proto-salt, from the tendency which the protoxid has to pass to the state of peroxid. They are, in general, of a yellowish colour, and, like other metallic salts, are decomposed by the alkalies. They also, however, sometimes enter into union with them, forming triple compounds. On the addition of ammonia to a per-salt, the peroxid is deposited in union, apparently with part of the alkali, forming a compound, in which the oxid seems to act the part of an acid.

The metals yet to be described differ from the preceding in this respect, that they enter into union with oxigen, and form acids, at least in so far, that they form salts by combining with the alkalies, earths, and metallic oxids. They ought therefore, perhaps, to be brought in along with acidifiable bodies, but as they have not yet been satisfactorily established to belong completely to this class, I have thought proper to allow them to remain with the metals.

CHROMIUM.

Chromium was discovered by Vauquelin in 1797 in an ore long mistaken for red lead, and in which it was found to exist united with that metal. It has since been detected in other minerals, but particularly in that lately discovered by Hibbert in the Shetland Islands, and now known by the name of *Chromate of Iron.*

We are very little acquainted with chromium in its metallic state, having been as yet obtained in small quantity, and of course not put to any use.

It is of a whitish colour, similar to that of iron. Its sp. gr. is 5900. Its atomic weight 35.

Its compounds, however, are valuable from the richness and durability of their colour, and consequently from their application in the arts.

Compounds with Oxigen.

Chromium combines with three proportions of oxigen, forming a green, or *protoxid;* a brown, or *deutoxid;* and an acid called *chromic.*

Chromic Acid.

Chromic acid is procured by digesting repeatedly the

chromic iron ore with nitre, by which the metal is acidified, and unites with the potassa, forming chromate of potassa; and by mixing this with nitrate of baryta, and then decomposing the chromate of baryta by sulphuric acid, the sulphate of the earth is deposited, and chromic acid left in solution. By filtration and evaporation, ruby-coloured crystals may be obtained.

Chromic acid unites with salifiable bases, and form salts called *Chromates.*

Deutoxid.

Deutoxid was prepared by Dr Thomson, by digesting chromate of soda with alcohol, by which it changed from yellow to green, the chromic acid having become protoxid. By evaporation to dryness, and digestion with nitric acid, the residue assumed the appearance of the brown or deutoxid, but supposed to be in union with soda.

Protoxid.

Protoxid may be procured by the addition of tartaric acid to the solution of a chromate, by which the chromic acid becomes protoxid, and remains in solution combined with the acid, but can be thrown down by ammonia; in which state it is a light tasteless powder, containing, after being dried by a slight heat, 86.7 per cent. of water, or 1 atom of oxid to 26 of water, the largest number of atoms known to exist in any hydrate. (First Prin.)

It is insoluble in water, but soluble in acids, forming salts. The muriate is soluble, and of a fine green colour. The sulphate is insoluble, but the colour is not so rich.

The composition of these oxids has not been established by experiment; but partly from reasoning on the atomic proportions, and partly from the analysis of the chromates, Dr Thomson has given the following as their constituent parts:

	Metal.	Oxigen.	Metal.	Oxigen.
protoxid,	100	28.5	1 atom	1 atom
deutoxid,	100	57.	1 atom	2 atoms
chromic acid,	100	85.5	1 atom	3 atoms.

The only one of these compounds, of any interest, is the acid which forms, with some of the salifiable bases, very important compounds.

Chromate of Potass.

This salt is prepared by fusing chrome iron ore with half its weight of nitre, and dissolving the residue in water, adding nitric acid to saturate the excess of alkali, and crystallizing the undecomposed nitre by evaporation. The residual fluid, when poured off and evaporated, will yield crystals of chromate, of a bright yellow colour, so intense, that a grain will give a yellow tinge to about 40,000 of water.

It is soluble in about twice its weight of cold water, and in any quantity of it at a boiling heat.

It is composed, according to Thomson, of

acid,	52	1 atom
potass,	48	1 atom,

and is therefore anhydrous.

It is easily decomposed by other re-agents; and hence the methods of preparing the different compounds of chromium. Its decomposition by nitrate of baryta, with the view of procuring chromic acid, has been already noticed.

Bi-chromate of Potass.

When the solution of the chromate is acidulated with sulphuric acid, it gradually deposits crystals of a rich red colour, and which, on analysis, are found to be *bi-chromate*, part of the alkali having been abstracted by the sulphuric acid.

It is soluble in about 10 of cold water, the solution being of a deep orange colour.

According to Thomson, it is composed of

acid,	68.5	2 atoms
potass,	31.5	1 atom.

The properties of the other alkaline, and of the earthy chromates, have not been examined.

The metallic chromates are all formed by the decomposition of the chromate of potassa, and as they are of different colours, and not liable to change, they are much employed in dyeing and in calico-printing; and hence the chief use of the alkaline chromates.

On adding a solution of nitrate, or of sugar of lead, to that of bi-chromate of potass, a rich yellow precipitate is formed, now much used in the arts under the name of *chrome yellow*, 2 of the nitrate by weight being requisite for the decomposition of 1 of the alkaline salt.

The same powder may be formed by the addition of the salt of lead to the solution of the product obtained by fusing the ore with nitre, having previously saturated the excess of alkali by nitric acid.

When carbonate of lead is boiled with solution of bi-chromate of potass, a sub-chromate of lead, of a beautiful red colour, is produced; or it may be obtained by a process recommended by Grouvelle, (An. de Ch. et de Ph. xix.) which consists in boiling the chrome yellow in solution of potassa, till it becomes of a bright red colour.

This, according to Badams, (An. of Ph. 1825.) is a *sub-chromate*, composed of 1 atom of acid and 2 of oxid. It is recommended by him as a durable paint, and as a valuable dye-stuff.

The yellow chromate is itself much used in dyeing.

Chromate of potassa, with solution of nitrate of silver, gives a dark red; with a salt of mercury, a fine red; with salt of copper, a brown precipitate.

Since chromate of potassa is thus so easily decomposed, and affords different colours with metallic solutions, it becomes a valuable substance in dyeing and calico-printing.

Chromium is supposed to exist in the red ore in which it was discovered in the state of acid; and in the common chrome iron ore, or chromate of iron, as it is usually called, it is, according to Thomson, in the state of deut-oxid, in combination with oxid of iron. It has been lately detected, also, in the grains of crude platinum, probably in the same state as in the ore of Shetland.

MOLYBDENUM.

The mineral called *molybdena*, resembling plumbago in its appearance, and long mistaken for it, was by Scheele first found to yield a peculiar acid, afterwards shewn by Hielm to be a compound of oxigen and a metal, to which he gave the name of *molybdenum*. The process by which he succeeded in procuring it, consists in roasting the ore till it is reduced to the state of a very fine powder, dissolving it in aqua ammoniæ, filtering and evaporating the solution. The residuum, when digested with nitric acid, becomes a white oxid, from which the metal is obtained in the usual way, by exposure to heat with charcoal.

As thus obtained, it is in the state of small grains, of a silvery whiteness. Its sp. gr. is 8600; and its atomic weight 60. It is not fused even by the most intense temperature yet applied to it.

When exposed to heat in an open vessel, it combines with oxigen, and is gradually converted to a white powder, which, by continuance of the heat, is volatilized.

Compounds with Oxigen.

Molybdenum unites with three proportions of oxigen, forming a *brown oxid*, and *two acids*.

Molybdic Acid.

Molybdic acid is obtained, as already mentioned, in the first part of the process for procuring the metal, or by adding nitric acid to the ammoniacal solution of the roasted ore, by which it is precipitated.

As thus procured, it is in white scales, but which, when melted and sublimed, become yellow. It changes vegetable blues to red.

Molybdous Acid.

Molybdous acid is obtained by triturating in a mortar,

with boiling water, a mixture of 2 parts of molybdic acid, and 1 of metallic molybdenum, by which a blue solution is formed. The whole is then boiled, filtered, and evaporated, by a heat not exceeding 120, by which the oxid is left in the dish. On repeating the process with the insoluble matter on the filter, more may be obtained, as the decomposition of the molybdic acid goes on very slowly. This oxid is also procured by boiling a mixture of molybdic and muriatic acids, evaporating to dryness, and exposing to heat, to expel any excess of the latter. In this instance the hydrogen of the muriatic must unite with the oxigen of the molybdic acid, to reduce it to the state of deutoxid; of course, chlorine must be liberated.

This compound possesses acid properties, and hence called molybdous acid. It is of a blue colour, soluble in water, reddens vegetable blues, and unites with bases, forming salts.

Protoxid,

According to Thomson, may be procured by dissolving molybdic acid in ammonia, evaporating to dryness, exposing the residue to a white heat with charcoal, by which a brown powder is found lying at the bottom of the crucible, and which is the oxid.

The proportions of these oxids have been given by Thomson, (First Pr.),

	Metal.	Ox.	Metal.	Ox.
protoxid,	100	16.6	1 at.	1 at.
molybdous acid,	100	33.2	1 at.	2 at.
molybdic acid,	100	49.8	1 at.	3 ats.

Sulphuret.

Sulphuret of molybdenum may be obtained by exposing to heat a mixture of 1 of molybdic acid, and 5 of sulphur, by which the oxigen of the former is expelled, and sulphuret is formed. It is similar in its composition and properties to the native ore, being, according to Bucholz, composed of

metal, 100 = 1 atom
sulphur, 66.5 = 2 atoms,

so that it is *Bi-sulphuret.*

Salts.

Both of the acids of molybdenum unite with the salifiable bases.

Molybdates of the alkalies of lime, magnesia, and cobalt, are soluble; but those of the other earths, of iron, copper, tin, lead, zinc, mercury, manganese, silver, and platinum, are insoluble.—(Thomson, First Pr.)

The molybdates are easily decomposed by sulphuric, nitric, muriatic, phosphoric, arsenic, and chromic acids, so that they have a stronger affinity than molybdic acid for the bases. They are also decomposed by the salts of those metals that have a strong attraction for oxigen, by which molybdous acid is formed. Thus, a piece of zinc causes the solution to become blue, and protomuriate of tin throws down a blue precipitate from the molybdate of potass.

The molybdates of many of the metals are insoluble, hence molybdic acid throws down precipitates from metallic salts, as from those of lead, mercury, and silver.

Molybdenum and its compounds have not, as yet, been put to any use.

TUNGSTEN.

The mineral called *tungsten* was, by Scheele, first proved to contain a peculiar acid in union with lime, and to which he gave the name of *tungstic* acid. The same acid was detected by D'Elhuyar, in the German mineral called *wolfram*, in which it is united with iron, tin, and manganese.

When tungsten, consisting of tungstate of lime, is exposed to heat with carbonate of potassa, tungstate of potass is formed, from which the acid may be precipitated on the addition of nitric acid. The same action takes place with wolfram, when treated in a similar manner.

Tungstic acid, when exposed to heat with charcoal, affords tungsten in its metallic state.

Tungsten is of a greyish colour, like that of iron. Its sp. gr. is 1740; its atomic weight, according to Thomson, 1575. It requires for its fusion a temperature of about 170 W.

Compounds with Oxigen.

When heated in air it is oxidated, forming two compounds, an oxid and an acid; the former of which is of a brownish colour, and is inflammable, uniting with the oxigen of the air, and forming *tungstic acid.*

Tungstic Acid.

Tungstic acid, procured in the first part of the process for obtaining the metal, is of a yellowish colour, insoluble in water, and requiring a most intense heat for its fusion. It does not redden vegetable colours.

When hydrogen gas is passed over it at a red heat, water comes off, and a brown-coloured substance is left, which is the oxid.

According to Berzelius, the composition of these compounds is,

	Oxid.		Acid.	
tungsten,	86.2	1 atom	80.5	1 atom
oxigen,	13.8	2 atoms	19.5	3 atoms

Salts.

Tungstic acid unites with the bases, and forms salts called *tungstates.* Its affinity for them seems to be weaker than that of sulphuric, nitric, and muriatic, but stronger than that of phosphoric, arsenic, and chromic acid; the three first decomposing the tungstates, while the three last have no effect on them.

The tungstates of the alkalies are soluble; but those of lime, baryta, strontia, alumina, iron, copper, lead, tin, zinc, mercury, manganese, silver, and cobalt, are insoluble; hence salts containing these metals throw down precipitates, when mixed with an alkaline tungstate, which are white, with the exception of those from

iron and cobalt, the former being yellowish, the latter of a pink colour.—(Thomson, F. Prin.)

TELLURIUM.

Tellurium was first noticed by Muller in a gold ore found in Transylvania. Its properties have since been examined by Klaproth, Gmelin, Davy, and Berzelius. The process followed by Klaproth, for procuring it, consists in dissolving the ore in nitro-muriatic acid, adding potassa in excess, which precipitates the metals, and keeps a compound of tellurium in solution. On the addition of muriatic acid, a precipitate appears, which, when heated with charcoal, yields tellurium.

Tellurium is of a colour resembling that of lead, having considerable lustre, and a foliated texture. Its sp. gr. is only 6000. Its atomic weight, deduced from the experiments of Berzelius, is 40. When heated in close vessels, it is melted at a temperature nearly the same as that required for fusing lead, and at a little higher heat, it is volatilized, the vapour condensing in minute globules in the cool part of the apparatus.

Compounds with Oxigen.

When heated in contact with air, it burns with a blue flame, tinged with green at the edge, and gives off a white smoke, which, when collected, is found to be a compound of the metal and oxigen, having the properties both of an acid and oxid; hence it forms salts, by its union both with acids and oxids.

According to Berzelius, it is composed of

metal,	100	1 atom
oxigen,	24.8	1 atom.

This oxid may be procured by the same process as that followed in obtaining the metal; indeed, the precipitate thrown down by muriatic acid from the alkaline solution, is oxid of tellurium.

Telluretted Hydrogen.

Tellurium unites with hydrogen, and forms a gaseous compound, called telluretted hydrogen, discovered by Davy in 1809, (Ph. Tr. 1810.)

It is prepared by first forming an alloy of tellurium and potassium, by exposing potassa, oxid of tellurium, and charcoal, to a red heat, and which, when put into a retort along with sulphuric acid, gives off the gas, the water in the acid affording oxigen to the potassium, and hydrogen to the tellurium.

It is a transparent colourless gas, having a disagreeable smell, somewhat similar to that of sulphuretted hydrogen.

When heated in contact with air, it burns with a blue flame, generating water and oxid of tellurium.

It is soluble in water, forming a claret-coloured solution, which decomposes most of the metallic salts, throwing down precipitates from them.

It unites with the alkalies, and affords compounds similar, in many respects, to those containing sulphuretted hydrogen, at least in their action with air, being easily decomposed by it.

According to Berzelius, it is composed of

tellurium 100, hydrogen 3.1.

and as 100 : 3.1 : : 40 : 1.24,

so that it may be considered to contain an atom of each of its ingredients.

Salts of Tellurium.

Tellurium is easily dissolved by acids, forming solutions which are decomposed by the mere effusion of water; but if much be employed, the precipitate is re-dissolved.

The alkalies, and their carbonates, also throw down precipitates, soluble in excess of the precipitant, from which the acid properties of the oxid have been inferred.

The acid solutions of tellurium are also decomposed by those metals which have a strong attraction for oxi-

gen, as zinc, iron, and tin, the tellurium being deposited in its metallic state. Ferro-cyanate of potass does not cause any change *.

TITANIUM.

Titanium was discovered by Mr Gregor, in a mineral found in Monachan, in Cornwall; but he did not succeed in procuring it in its metallic state. Klaproth afterwards observed it, in the form of oxid, in a mineral called *red shorl*, and Vauquelin first obtained it pure, since which, its properties have been examined by Lowitz and Laugier. It has lately been discovered by Wollaston, in its metallic form, in the slag of the iron-work at Merthyr Tydvil, in Wales.

Titanium is procured from the mineral called *titanite*, by fusing it with potassa, washing the residuum, and dissolving it in muriatic acid, and to the solution adding oxalate of ammonia, by which oxalate of titanium is deposited. On exposing this to a red heat, the acid is consumed, and the oxid left, which Laugier endeavoured to reduce to its metallic state, by exposure to heat with charcoal, but the results were by no means satisfactory.

We are indebted to Dr Wollaston, for what we know of the properties of titanium in its metallic form, (Ph. Tr. 1823.) The small cubes found in the slag of the iron-work at Merthyr Tydvil, are, according to him, titanium, very nearly in a state of purity.

It has a colour similar to that of copper; is brittle, but extremely hard, so much so, as to scratch rock crystal. Its sp. gr. is 5300. It has not been fused by the most intense heat yet applied. When heated in contact

* From what has been said of the properties of tellurium, it appears to belong rather to the class of acidifiable bodies than to those forming bases. If future experiments establish this opinion, it will probably be classed along with sulphur, or those substances forming acids with oxigen, and with hydrogen.

with air, it is slowly oxidated, but the oxidation may be promoted by admixture with nitre.

Oxids.

Titanium forms two oxids, a *protoxid* of a bluish colour, and which exists native in the mineral called *anatase*, and a *peroxid* supposed to be possessed of acid properties. It is the last which exists in menachanite, and in red shorl, the minerals in which it was discovered by Gregor and Vauquelin. It may be obtained by the process already mentioned, or by that followed by Rose, which consists in fusing red shorl, with carbonate of potass, dissolving the mass in muriatic acid, and precipitating by ammonia. The precipitate, consisting of the oxid of titanium and iron, is then kept in a close vessel with hydro-sulphuret of ammonia, by which the iron is gradually converted to sulphuret, and by washing with muriatic acid is removed, leaving the oxid pure.

It is white, but on being heated becomes yellow, regaining its whiteness on cooling. When laid on litmus paper, and moistened, the fluid becomes red, but the colour of the paper is not changed.

It is soluble in acids, forming solutions which yield precipitates on the addition of alkalies and their carbonates.

It appears to enter into union with the alkalies, and form peculiar compounds, and hence it is supposed to have the properties both of an acid and a base.

The acid solution of titanium is decomposed by some of the metals. Zinc, when immersed in it, gives the fluid a blue, and tin a rich red colour.

It is decomposed also by hydro-sulphurets, and ferrocyanates, the former yielding a greenish, the latter an orange-coloured precipitate.

Chlorid.—When chlorine gas is passed over the cubes of metallic titanium, it is absorbed, and a compound formed, which is condensed in the cool part of the tube. It is transparent and colourless, emits white fumes by exposure to air, and boils at a temperature below 212. When

touched by water, there is an immediate disengagement of chlorine gas, and muriate remains in solution.

Wollaston attempted to form alloys of titanium, but without success. The atomic weight of titanium is, according to Thomson, 40, that of titanic acid 60.

COLUMBIUM.

Mr Hatchett, when engaged in the analysis of a mineral brought from Massachussets, discovered a substance in the state of oxid, or rather of acid, and to the base of which, though he did not succeed in obtaining it, he gave the name of *columbium*. Eckeberg shortly afterwards discovered a similar compound in the minerals named *tantalite* and *yttrotantalite*, and which he proposed to call *tantalum*. These substances have, however, been shown by Wollaston, (Ph. Tr. 1809.) to be the same; he has therefore rejected the latter name, and retained that of columbium, given it by its original discoverer.

We are indebted to Berzelius, (An. of Ph. viii.) for the first successful attempt to procure columbium in its metallic state. When any of the minerals containing columbic acid is fused with carbonate of soda, and sulphuric acid is added to the solution after filtration, a white powder is precipitated, which is columbic acid, and which is reduced when exposed to an intense heat with charcoal.

Columbium is of a dark grey colour, with considerable lustre. Its sp. gr. according to Wollaston, is 5600; but in his experiments it had not been melted, so that it is probably above this. When heated in air, it takes fire, and burns with a feeble flame.

It is not acted on by nitric, muriatic, or nitro-muriatic acid; but when fused with potassa, it is oxidated. It is also oxidated, or rather acidified, by fusion with nitre.

Columbic Acid.

Columbic acid, prepared by the process already de-

scribed, is a white, tasteless powder, very sparingly soluble in nitric, muriatic, and sulphuric acids. It is easily dissolved by potassa and its carbonate, forming a colourless solution, from which it is precipitated on the addition of an acid.

The hydro-sulphurets, and ferro-cyanates, do not throw down any precipitate from the alkaline solution.

The salts of copper, lead, zinc, mercury, manganese, and silver, produce a white flocculent precipitate.

Berzelius, by an analysis of columbic acid, has fixed its proportions at

metal, 100 oxigen, 5.48.

And Thomson, from an analysis of columbate of soda, prepared by fusing the acid and alkali, dissolving the product in water, and crystallizing, considers the atomic weight of the metal to be 180, which very nearly agrees with that deducible from Berzelius's analysis of the acid; for, considering it to contain an atom of each of its ingredients,

as 5.48 : 100 : : 10 : 182.

The columbic acid precipitated from its solution, is, in the state of hydrate, composed, according to Thomson, of 1 atom acid, and 7 of water; and the columbate of soda he found to consist of 1 atom acid, 1 atom soda, and 10 of water.

PART III.

VEGETABLE CHEMISTRY.

SECTION I.

All vegetables have a distinct form, and their internal structure is very delicate, but these vary in almost every class. Notwithstanding this great diversity, they do not contain many ingredients; indeed, with the exception of a few, their component parts are, oxigen, hydrogen, and carbon, along with which, some contain also nitrogen. There are also saline, earthy, and metallic matter, but which are in very minute quantity, and must not be considered essential ingredients, being derived from the soil; hence they differ according to the locality of the plant.

The elements contained in vegetable matter are derived from the soil, from rain, and from the air. By the living powers of the plant, they are made to enter into particular states of combination, and thus form the different parts of vegetables, and the various principles they contain.

The elements of the vegetable kingdom enter into union, so as to form what are called *Vegetable Principles.* Some of these are contained in all plants, while others are afforded by particular vegetables only. Some are dispersed through the whole plant; others, on the contrary, are confined to particular parts.

Before proceeding to detail the nature and composition of these, it may be proper to give a view of their general properties, by which a great deal of useless repetition will be saved.

Properties of Vegetable Matter in General.

When vegetable matter, wood for instance, is subjected in close vessels to a heat, not very intense, water is given off. If the temperature be increased, its texture is destroyed; water, containing the acid of vinegar, having an empyreumatic odour, and mixed with a dark-coloured oily liquid, is distilled over, along with a large quantity of gaseous fluid, consisting chiefly of carbonic acid and carburetted hydrogen. When these have ceased, charcoal is left, retaining the form of the wood, and containing a minute quantity of saline, earthy, and metallic matter.

The substances disengaged during this process, are all the result of new combinations into which the elements have entered. Thus the water, or at least the greater part, is formed by the union of oxigen and hydrogen, while the carbonic acid, and carburetted hydrogen, are produced by part of the carbon and oxigen, and of the carbon and hydrogen, having united.

The application of heat to vegetable matter, constitutes what is called the *destructive analysis*, as in this way the proportions of the elements may be discovered; for by collecting the products, and finding the quantity of each, the proportions of their constituents, and of course of those of the vegetable, are ascertained.

When vegetable matter is heated in air, it burns, yielding carbonic acid and water, and it is ultimately consumed, leaving only a minute quantity of saline, earthy, and metallic ingredients. This forms another mode of analysis, at one time practised, though now given up, others more accurate having been introduced.

When vegetable matter is subjected to the action of

water, some of its principles are dissolved, and the solution, on evaporation, yields a substance called *Extract.*

The acids in general act easily on vegetable matter, the action depending on the acid employed. When nitric is used, there is a disengagement of gas, and the formation of other acids. If it be diluted, it is necessary to apply a slight heat. Nitric oxid and carbonic acid gas are disengaged, and a transparent colourless solution is left in the retort, containing in general the acids called *Oxalic* and *Malic.*

When vegetable matter is put into sulphuric acid, it is instantly charred, and a dark-coloured solution is formed, which, when thrown into water, yields a black carbonaceous precipitate. With the aid of heat, the vegetable substance is soon dissolved, and carbonic and sulphurous acids are disengaged, so that the carbon must take oxigen from the sulphuric acid.

The action of some of the salts is interesting, as forming an excellent mode of analysis. That principally employed for this purpose, is chlorate of potass. When it is mixed with vegetable matter, and exposed to heat in close vessels, water, carbonic acid, and occasionally carburetted hydrogen, are given off, and if the salt has been used in excess, oxigen is also set free. This method of decomposition was first pointed out by Gay Lussac and Thenard, and practised by them in analysis with great success. In conducting it, the salt and vegetable matter are dried at a temperature not exceeding that of boiling water. They are then mixed in the proper proportions, put into the apparatus, and subjected to heat, the products being collected over mercury. The proportions of the gases disengaged being ascertained, and deducting from them the oxigen given off from the chlorate, a known quantity of which has been used, the elements of the vegetable matter are discovered, (Thenard's Analytical Chemistry.)

Instead of the chlorate of potass, peroxid of copper is now generally used in the analysis. The vegetable matter, mixed with the oxid, being placed in a glass tube, is

heated by means of a spirit lamp, and the gaseous fluid, as in the other instance, collected over mercury. Different forms of apparatus are used by different chemists. Perhaps the simplest is that of Mr Cooper, (An. of Ph. N. S. vii.) That recommended by Dr Ure, is described in Ph. Tr. 1822.

By this mode of analysis, Gay Lussac and Thenard have discovered the composition of a number of substances, and they have also drawn the following conclusions:—

1*st*, That when the vegetable has more oxigen than will form water with the hydrogen, it is *acid*.

2*d*, When the oxigen is to the hydrogen in less proportion than will form water, the vegetable is *oily*, or *resinous*, or *alcoholic*.

3*d*, When the oxigen and hydrogen are in such quantity as to form water, the vegetable is neither acid, nor resinous, nor oily, but in the state of *gum*, *starch*, *sugar*, &c.

Some exceptions to these general laws have, however, been noticed by Saussure (An. of Ph. vi.) and others.

Vegetables also undergo spontaneous changes, by which their nature is completely altered, and new substances are formed. This process is called *fermentation*, and is divided into three kinds, the *vinous*, *acetous*, and *putrefactive*; the first so called, because, during it, vinous or spirituous fluid is formed; the second, because vinegar or acetic acid is produced; and the third, because the vegetable undergoes putrefaction, being almost entirely dissipated in the form of gaseous products.

Sugar is the substance that assumes the spirituous fermentation most easily, and by converting other bodies to the saccharine state, it causes them to undergo this change more readily. When sugar is dissolved in water, and a little yeast is added, the mixture soon becomes muddy, bubbles of gas rise through it, and it acquires a thick scum on its surface. When these have gone on for some time, the scum falls to the bottom, and the fluid again becomes transparent; its properties are also alter-

ed; it has lost its sweetness, acquired a hot pungent taste, and produces intoxication.

These changes are easily observed, by putting a pound of sugar, with 6 of tepid water, and a little yeast, into a glass flask, so as to occupy about one-half of its capacity, adapting a bent tube to this, and carrying it under a jar, resting on the shelf of a water-trough. The gas, when examined, extinguishes combustion, and renders lime water turbid; it is therefore carbonic acid.

When vinous fluids are exposed to the air, they become turbid; their temperature rises, and a scum collects on the surface; but they soon again become transparent, lose their grateful flavour and intoxicating quality, and acquire a sour taste. In this case, the product is *vinegar*, which contains *acetic acid* as one of its ingredients.

When the product of this fermentation is exposed to the atmosphere, the putrefactive process commences; it becomes opake, acquires a disagreeable smell, and in the course of time, almost the whole of it is consumed, leaving only a little carbon and earthy matter.

Vinous Fermentation.

There are different circumstances necessary to cause the commencement, and favour the progress of vinous fermentation; such as, a certain quantity of water, a proper temperature, and in general, the addition of a body called a *ferment*. The temperature ought to be from 50 to 80; when below the former, it goes on slowly; the nearer it is to the latter the better, but it must not be allowed to go beyond it, as the acetous fermentation is apt to begin. The substance added to induce the change, called *yeast*, is the scum and sediment collected from liquids in which fermentation is going on, and which is supposed to act, by inducing the operation of affinities different from those by which the ingredients are held together.

Though exposure to air favours vinous fermentation,

it is not necessary, for if by any means the gaseous fluid which is generated, is allowed to escape, as in the experiment with the sugar, it goes on, though not so speedily. On the other hand, free admission of air, though it expedites the process, weakens the product, by carrying a great deal of it off by evaporation.

By vinous fermentation, are produced the different liquors possessed of intoxicating quality; they may be divided into two kinds, the *vinous*, obtained from the juices of plants, and the different kinds of *beer*, procured from the infusion of seeds.

The process of making wine is very simple. From grapes there is expressed a juice called *must*, which contains sugar, jelly, and cream of tartar. When kept at about the temperature of 70, fermentation commences, and goes on with the usual phenomena; and after it has ceased, the liquor is put into casks, where it slowly deposits the substance called *tartar*, which is composed chiefly of cream of tartar and the colouring matter of the wine.

The colour of wine is communicated by the husks, which are mixed with the fermenting fluid, and the sparkling wines, as champaign, derive this property from their containing a large quantity of carbonic acid, generated during the fermentation, the wine being bottled before this process is finished.

Malt liquors, as the other kinds of fermented fluids are called, are obtained from grain, for which purpose barley is used; but before inducing fermentation in it, it is previously converted into *malt*. For this purpose, it is put into a large trough, and mixed with as much water as merely covers it, where it remains for two or three days, the time depending on the weather; the warmer the season, the less being required. Here it imbibes moisture, emits carbonic acid, and the water dissolves a little of it, particularly of the husk. This process is called *steeping*. When completed, the grain is spread on the malt floor to about the depth of 16 inches, where it begins to grow warm, and it emits a pleasant odour, re-

sembling that of apples; it also becomes moister than before; hence this stage of the process is called *sweating*. When these have taken place, the roots of the grain shoot forth, and in the course of another day, the future stem, called *acrospire*, begins to appear. To put a stop to the farther progress of the changes that are going on, the depth of the grain is gradually diminished, till at last it is only about 3 inches deep, after which it is put into a kiln and subjected to heat, at first slight, but afterwards gradually increased, till it is sufficiently dried. By this last part of the process, the *germination* is stopped, the malt is then put into wire sieves and shaken, by which the roots, or *commings* as they are called, which were formed during the first stage, are removed.

Having procured malt, the next operation is to subject it to *brewing*, which consists of five parts, *mashing*, *boiling*, *cooling*, *fermenting*, and *cleansing*. The malt, after being bruised, is put into a mash tun with about an equal quantity of water at 180, and well stirred. After remaining there for a few hours, the fluid is drawn off, and the process repeated, till the whole of the soluble matter is extracted. The product called *wort* is a dark brown liquid, having a sweet taste, which it has acquired from the saccharine matter of the malt. It is pumped off into boilers, in which it is boiled for some hours, till it becomes of the requisite strength, and which is known by the use of a *saccharometer*, *(See Appendix,)* the substance, during this stage of the process, being added, which communicates the proper flavour. That employed is *hops*, which contain an oily matter, and a bitter principle, both of which are extracted by the wort, and impart their qualities to it. When the wort is properly boiled, it is drawn off into the *coolers*, large shallow troughs placed in apartments, in which there is a free ventilation. Into these it is poured to about the depth of three or four inches, so that it may cool as quickly as possible, and thus be prevented from becoming sour. When cooled, it is run off into the fermenting vats or *gyletuns*, and mixed with the requisite quantity

of yeast, by which fermentation is induced; bubbles of gas come off, and a scum arises to the surface, the temperature at the same time increases, in general, from about 12 to 15 degrees. After it has gone on for a few days, it becomes languid, the wort and the froth collected on its surface are then well mixed, by which it again commences, and continues for some time; at last the fluid diminishes in the vat, owing to the air bubbles escaping from the froth. When it has arrived at this state, it is necessary to stop the fermentation, otherwise the scum would mix with the fluid, and not only give it a bitter taste, but cause it to become sour. It is therefore drawn off into barrels, which are filled quite up to the bung hole. In these the fermentation again begins, by which a scum rises to the surface; and as they are always kept full, by occasionally pouring in a little of the liquor, it *works over*, the scum is therefore thrown out, and thus prevented from mixing with the fluid, at the same time part of the yeast falls to the bottom, forming the dregs; hence this part of the process is called *fining*. When the fermentation has stopped, which is known by the froth ceasing to work over, the barrels are bunged, and are ready for the market.

The process now described, is that followed in making *ale* and *beer;* the brewing of *porter* is carried on in the same way, with this difference, however, that the malt is prepared in a peculiar way. It has been already said, that that used for ale is dried by the application of a slight heat. In making malt for porter, a much higher temperature is applied, by which it is slightly burned, so that the wort got from it has a dark colour, and a peculiar bitter taste *.

All vinous and malt liquors contain a quantity of *spirit of wine*, or *alcohol*, formed during the fermentation, which is the cause of their intoxicating quality, and which

* Though porter may be prepared by the process described, it is well known that other substances are also used, which, though not absolutely necessary, add to its flavour and appearance.

can be procured from them merely by distillation. Hence the mode of making whisky, rum, gin, brandy, and other spirituous fluids.

The substance generally employed in making *whisky*, is barley, but others are occasionally used, as sugar, molasses, carrots, turnips, &c. When grain is used, it is generally malted, as has been already described; but it is occasionally employed in its raw state. *Distillation*, as the making of whisky is called, consists of four parts, *mashing*, *cooling*, *fermenting*, and *distilling*, the three first of which are carried on nearly in the same way as in brewing; the wort being obtained by mashing the malt, and then cooling it as quickly as possible, and after mixing it with the requisite quantity of yeast, making it undergo fermentation, by which the sugar it contains is gradually decomposed, and converted into alcohol, or spirit of wine, by which the specific gravity of the fluid is diminished; it is therefore said to be *attenuated*. Spirit of wine has the power of stopping fermentation, so that when generated in too great quantity in the fermenting tun in proportion to the water, it prevents in a great measure the process from going on, consequently part of the sugar is not decomposed, and converted to spirit; it is of importance, therefore, to keep the fluid weak.

The liquid thus procured, called *wash*, is subjected to distillation as soon as the fermentation has ceased, otherwise it becomes sour, the distillation being continued, till the fluid which comes over is of the specific gravity of water, and which is known by the use of an *areometer*, *(See Appendix)*; what is left in the still is called *spent wash*, and is used for feeding cattle. The liquid obtained by the first distillation is termed *lowines*; it contains about a fifth part of its weight of alcohol. It is subjected to a second distillation or *doubling*, and the process continued till the fluid is got of the requisite strength, which is by order of government 909, water being 1000.

In carrying on distillation when the duty was levied according to the time the still was in use, it was neces-

sary to put in a piece of soap, the oily matter in which rose, and spread over the surface of the wash, and by breaking the large bubbles, prevented it from coming over, or *running foul;* and hence the disagreeable soapy taste that whisky had; besides, it contained more of a peculiar essential oil, derived from the malt. Distillers now pay duty according to the *strength* of their wash, and the *quantity* of spirit, taking care that the latter is of the proper specific gravity; hence it is that whisky is now far superior to what it formerly was, the spirit being distilled off more gradually, and bringing with it less of the substances that gave it the disagreeable flavour.

Gin, or *Hollands*, is always prepared by the Dutch. The wash employed is procured by fermenting a mixture of malt and *rye*, and after the fermentation is completed, it is put into the still along with juniper berries, and the distillation carried on in the usual way, by which a spirit is obtained having a peculiar flavour, derived from the junipers *.

Rum is procured by subjecting to distillation, a fermented fluid prepared from the refuse in the operation for making sugar; the peculiar flavour being derived from an essential oil existing in the juice of the cane, and which is brought off by the spirit. The product of the distillation, which is repeated till it is of the proper strength, is colourless, but is afterwards coloured by the addition of a little burnt sugar.

Brandy is obtained merely by distilling wine, of course its strength and flavour must depend on those of the wine. The distillation is performed in the usual way, by which a colourless spirit is procured, which is afterwards coloured, by mixing with it some burnt sugar, and a dye called Saunders wood.

From all these substances, alcohol, or spirit of wine,

* The term *gin* is applied in London to a fluid, procured by the distillation of whisky along with juniper berries and oil of turpentine, while *Hollands* means the article prepared by the Dutch.

may be prepared. Whisky is employed in this country, and brandy on the continent. All that is requisite is to put the spirituous fluid into a still, and subject it to distillation, till about one half comes over. As thus procured, it is not pure; it still retains a good deal of water, and an essential oil, from which it may be in a great measure freed by repeated distillation from potashes, or from other substances having an affinity for water.

For this purpose any quantity of common spirit of wine is poured on sub-carbonate of potass, which has been heated to redness, and allowed to cool to about 300. The water and carbonate combine, and form a solution which, being heavier than the spirit, falls to the bottom, so that the latter may be drawn off clear. By repeating this process several times, and at last redistilling either from a little of the carbonate, or from dried muriate of lime, the alcohol is procured of much less specific gravity. By redistillation in this way, it is obtained very nearly free from water.

When spirit of wine is kept in a bladder for some time, or in a glass jar, the mouth of which is covered with it, the water gradually exudes through the pores, leaving the spirit much purer; and hence also a method of diminishing its specific gravity.

It was at one time disputed whether alcohol existed in vinous fluids, or was the product of the distillation; but it has now been proved by the most satisfactory experiments, that the heat serves merely to separate the component parts, the alcohol, being the more volatile, passing off in vapour. Thenard, for instance, has found that alcohol may be procured from wine by distillation *in vacuo*, and Brande has shewn, that it is separated by the addition of different re-agents without the application of heat. From his numerous experiments, Mr Brande has given a table of the quantity of alcohol in different kinds of vinous and malt liquors, (see Appendix.)

Alcohol.

Alcohol is a transparent colourless fluid, having a plea-

sant odour and a pungent taste, and more powerfully intoxicating than the fluids from which it is procured. Its sp. gr. varies according to the mode of preparing it; spirit of wine produced by the first distillation of whisky is about .860, but by a second it comes down to .835, which is the strength ordered by the pharmacopœia. In this state, however, it contains a considerable quantity of water; and hence the necessity of submitting it to the different processes described, (p. 144.). Saussure and others have succeeded in procuring it of sp. gr. about 794 at 60; but even in this state it is supposed to retain a little water.

Numerous tables have been given by Chaussier, Gilpin, and others, of the quantity of alcohol of a certain sp. gr. in fluids of different strength, (vid. Appendix.)

When strong alcohol and water are mixed, there is a condensation and consequent evolution of caloric, equal measures producing a rise of temperature of about 20 degrees. A remarkable exception, however, to this is mentioned by Thenard, with respect to spirit of sp. gr. 970, which, when mixed with an equal measure of water, gave a fluid of a density less, instead of greater, than the mean; so that there must have been a rarification, and of course a reduction of temperature.

Alcohol endures a very intense cold without congealing, having been subjected to the lowest temperature, yet accurately measured —91 without becoming solid. Mr Hutton has, however, asserted that he succeeded in freezing it, by exposing it to a cold of —110, but he has not thought proper to state his method of producing the reduction of temperature, nor has his statement been confirmed by any other, (An. of Phil. 1.)

Alcohol expands considerably by application of heat. According to Dalton, 1000 parts at 50, when raised to 110, became 1039, and at 1070 or double the distance from 50, they became 1073, so trifling a difference from twice the increase in volume, that the expansion may be considered as nearly uniform; and hence, along with the low temperature to which it may be exposed without

congealing, its value in the construction of thermometers.

Alcohol of sp. gr. 820 boils at 176, and when of 800 at 173.5. When, on the contrary, the density is greater, the boiling point becomes higher. *In vacuo*, when of sp. gr. 815, it passes off at 56 in vapour, the density of which at 50 is 1613, compared to air as 1000. During the evaporation, a great degree of cold is produced, as is shewn by the simple experiment of covering the ball of a thermometer with a piece of muslin, dipping it in alcohol, and whirling it in air, by which the temperature sinks below the freezing point.

When exposed to a high heat excluded from air, it is decomposed, water, carbonic acid, and carburetted hydrogen, being given off, while a little carbon is deposited in the tube through which it is transmitted. This experiment may be shewn by using the same apparatus as that for the decomposition of water, (p. 138. vol. i.), the alcohol being put into the retort, A, and the gaseous matter collected in the jar on the water trough; but before putting the end of the tube into the trough, it may be kept in a flask for some time, the inside of which will soon become dim from the deposition of moisture.

When heated in contact with air, it burns with a feeble flame, but giving out considerable heat and no smoke; and hence its use as a means of affording heat in carrying on operations on a small scale. For this purpose, it is consumed on a cotton wick, in a lamp, made either of glass or brass, and to the neck of which a cap is fitted to prevent the waste of the spirits when not in use. The temperature necessary for the combustion is about 300, and the products are carbonic acid and water: and that this is the case, is proved by holding a bell jar over a spirit lamp, by which it soon becomes dim from the deposition of moisture; and by throwing in a little lime-water, it becomes turbid from the formation of carbonate of lime.

These experiments are sufficient to shew that carbon, oxigen, and hydrogen, are the ingredients of alcohol;

and by this and other similar modes of analysis, the proportions have been determined with precision. Lavoisier, by burning a certain weight of it, and finding the consumpt of oxigen, fixed the proportions at

28.5 carbon, 7.8 hydrogen, 63.7 water.

The composition given by Saussure, (An. de Chim. lxxxix.), is very different from this, and his results have been confirmed by other experimenters. His experiments were conducted by burning the alcohol, by passing it through incandescent tubes, and by the transmission of electricity through its vapour when mixed with oxigen. The average of his results gives the composition,

carbon,	51.98	or 2 atoms
oxigen,	34.32	1 atom
hydrogen,	13.7	3 atoms.
	100.00	

In considering the composition of alcohol as given by Saussure, it is evident that the ingredients are just in proportion to form olefiant gas and water, for, uniting the 1 of oxigen with 1 of hydrogen, there are left 2 of hydrogen and 2 of carbon; so that, viewing it in this light, alcohol is composed of

olefiant gas,	2 atoms,	or 60.87
water,	1 atom,	or 37.13
	100.	

The sp. gr. of alcohol vapour, it has been already stated, is 1613. Now, if we consider it composed of olefiant gas and watery vapour, it must contain not only equal volumes of these, but they must be compressed into half their original volume. In the first place,

Weight of olef. Weight of water. Sp. gr. of olef. Sp. gr. of steam.

60.87 : 39.13 : : 972 : 624.8

again, $972 + 6248 = 1596.8$,

not far short of 1613; in fact, this, it is more than probable, is the real sp. gr. of alcohol vapour.

This analysis is important as tending to an explanation of the changes that take place during the formation of

alcohol; and, of course, of the phenomena of vinous fermentation. It will be afterwards shewn that sugar is composed, (see Sugar,) of an atom of carbon, oxigen, and hydrogen; and, supposing it to be the necessary article in the formation of the vinous product, the changes that have ensued are the disappearance of the sugar, and the formation of alcohol and carbonic acid. Gay Lussac, in accounting for the decomposition, (An. de Chim. xcv.) gives the following as the composition of the substances before and after fermentation, multiplying the ingredients of the sugar by 3, so as to have the hydrogen in it and in alcohol the same.

Atoms of	In sugar.	In alcohol.	In carbonic acid.
carbon,	3 = 22.5	2 = 15.	1 = 7.5
oxigen,	3 = 30.	1 = 10.	1 = 20.
hydrogen,	3 = 3.75	3 = 3.75	
	56.25	28.75	27.5

and $28.75 + 27.5 = 56.25$.

So that, according to this view of the subject, the only change effected on sugar during the vinous fermentation, is the resolution of it into alcohol and carbonic acid; and the above table shews that $56\frac{1}{4}$ of sugar, should yield $28\frac{3}{4}$ of the former, and $27\frac{1}{2}$ of the latter, supposing that there is no waste, but this is never to be expected in the common modes of conducting the process.

Alcohol dissolves phosphorus, and the solution exhales the odour of phosphuretted hydrogen. From it the phosphorus is deposited on the addition of water.

Most of the acids act powerfully on alcohol, but the results differ according to the proportions of the substances employed. When a large quantity of sulphuric acid is used, the mixture becomes black, and olefiant gas is disengaged; and hence the method usually followed in preparing it.

For this purpose 2 parts, by measure, of sulphuric acid, and 1 of alcohol, are put into a retort; and, after shaking the vessel to mix the materials, heat is applied, by which a gaseous matter is disengaged, and may be

collected over water. It is not, however, pure; it is mixed with a little carbonic acid, but from which it may be freed, by shaking it with lime water, or by using a lime water trough. Towards the end of the process, the mixture becomes thick, and froths up in the retort, and carbonic and sulphurous acids are disengaged; because, at the high temperature at which the action is going on, the carbon deposited from the spirit, unites with part of the oxigen of the sulphuric acid.

If we consider alcohol as composed of olefiant gas and water, then the change effected on it by the sulphuric acid in this instance, is merely the abstraction of the latter, for which the acid has a strong affinity, and the expulsion of the former. But, besides these, there is a deposition of carbon, and formation of other products, from part of the alcohol being resolved into its ultimate elements.

When the acid is employed in less proportion, the action is different, the product being a transparent colourless fluid, called *ether*; but the properties of ethers will be described after having given those of alcohol, with other substances.

Alcohol dissolves the alkalies, and forms solutions of a brownish colour. On the affinity between them depends the method of obtaining each, free from impurities, the former being deprived of its water by the addition of an alkali, (p. 144.), while the latter may be freed of its impurities by solution in alcohol. The preparation of alcoholic solution of ammonia, is a pharmaceutical process. For this purpose the Edinburgh Pharmacopœia orders

Quicklime, sixteen ounces.

Muriate of ammonia, eight ounces.

Water, eight ounces.

Alcohol, thirty-two ounces.

They are put into a retort, to which a receiver is adapted; and, by the application of heat, the lime acting on the salt, disengages the ammonia, which coming off with the alcoholic vapour, is condensed along with it in the receiver.

Alcohol dissolves many of the compound salts, while

it does not act on others.—A table of the salts soluble in it, is given in the Appendix.

When to any alcoholic solution of a salt, not soluble in water, water is added, there is an immediate precipitation, owing to the fluids uniting; and the same also occurs on the addition of alcohol to a watery solution of a salt not soluble in it.

The solutions of some of the salts burn with a peculiar flame. That of muriate of strontia is red; of copper, green.

The action between alcohol and some of the metals, particularly platinum, is remarkable. When a small piece of thin platinum leaf, suspended by a wire, is heated by a spirit lamp, and then quickly put into a glass, in which there is a little alcohol, so as to have it just over the surface, and of course in the vapour arising from it, it continues red hot, as long as there is any fluid in the jar, which is owing to the vapour undergoing a sort of combustion, and generating heat sufficient to keep the metal in that state. Hence the lamp without flame, which is merely a common spirit lamp, but having a spiral of platinum wire, about the thickness of the 1-50th part of an inch, placed round the wick, but not in contact with it. On kindling the spirit, the platinum becomes red hot, and on extinguishing the flame, the vapour coming off, keeps the metal ignited, so that, on applying a match, it kindles it, which also sets the spirit on fire.



Dalton and Henry have shewn, that in this instance the same products are formed, as when the alcohol is burned; in fact, it is merely combustion, but without flame.

Ethers.

The substances formed by the action of acids on alcohol are called *ethers;* and to distinguish them from each other, the name of the acid by which they are formed, is added. Thus we have *sulphuric, nitric* ether, &c.

Sulphuric Ether.

The preparation of sulphuric ether is a pharmaceutical process. The orders given in the Edinburgh Pharmacopœia are,

Take of alcohol and sulphuric acid, of each 32 ounces.

Pour the alcohol into a retort, add the acid, and instantly proceed to the distillation, by placing the body of the retort into a sand-bath, previously heated; and having adapted a receiver, distil off 16 ounces, which will occupy about an hour and a half. As the product contains a little acid and water, mix it with one-fourth of an ounce of caustic potass, and re-distil, till ten ounces are obtained.

If, instead of stopping the process in the first distillation, when the requisite quantity of ether has been obtained, the receiver be removed, and another put in its place, on the continuance of the heat, a fluid comes over, having an etherial odour, but mixed with an oily-looking matter, called *oil of wine*. There is, at the same time, a disengagement of olefiant, carbonic acid, and sulphurous acid gases, and the mixture swells, and is apt to flow over.

Sulphuric ether is a transparent colourless fluid, having a hot pungent taste, and strong fragrant odour, acting as a powerful stimulant to the animal frame.

Its specific gravity, when pure, is 632; but it is seldom got so low as this, being in general about 730, or even 750, owing to adulteration with alcohol.

It is very volatile, passing off quickly in vapour, even at a natural temperature. The vapour is easily procured, by throwing a little into a jar, covering it with a plate, and shaking it for some time, by which the whole of it disappears; of course, the vapour is not pure, being mixed with atmospheric air. During the evaporation, a great degree of cold is produced, more particularly if the process be conducted *in vacuo*. If, for instance, the bulb of a mercurial thermometer, surrounded with muslin, be placed under the receiver of a pump, and after

exhausting, ether be allowed to drop on it, the cold excited by the rapid evaporation, is sufficient to freeze the mercury.

The specific gravity of the vapour is, according to Dalton, 3250; according to Gay Lussac, 2586. Its elasticity, of course, varies according to the temperature. *(See Appendix.)*

Ether congeals at —46°, and boils at about 98; but the boiling point varies according to its specific gravity. When subjected to a strong heat, it is decomposed, carburetted hydrogen and an oily fluid coming off, and carbon being deposited.

When heated in air, it burns with a white flame, carbonic acid and water being generated, which may be shewn by the same process as with alcohol. The easy inflammability of ether, is beautifully illustrated by the application of heat to the mouth of the jar in which its vapour has been formed by agitation; or, by pouring a little on a piece of white sugar, and throwing it into a glass of warm water, the vapour is instantly given off, and may be kindled.

Ether does not act with oxigen at a natural temperature. When introduced into it over mercury, the elastic fluid is about doubled in its volume by the transmission of an electric spark; provided the oxigen is in excess, the mixture may be exploded, and carbonic acid and water are the results. Hence a method followed in the analysis of ether; and it has also been analyzed by transmitting its vapour through incandescent tubes. Different statements have, however, been given of its composition.

	Saussure.	Ure.	Thomson.
carbon,	67.98	60.	64.865
oxigen,	17.62	26.66	21.622
hydrogen,	14.40	13.34	13.513
	100.00	100.00	100.000

Considering the last as correct, ether is composed of

carbon, 4 atoms,
oxigen, 1 atom,
hydrogen, 5 atoms;

and if we suppose that

oxigen, 1 atom,
hydrogen, 1 atom,

are combined to form water, then there remain,

hydrogen, 4 atoms,
carbon, 4 atoms,

the constituents of olefiant gas.

Viewing it in this way, the composition may be stated to be,

olefiant gas, 4 atoms,
water, 1 atom;

but alcohol is composed (p. 147.) of

olefiant gas, 4 atoms,
water, 2 atoms;

so that the only difference between them, is 1 atom of water.

If this view of its composition be correct, we can easily account for the action during its formation,—the acid decomposing the spirit, and by its powerful affinity for water, removing one of its atoms, and setting the olefiant gas with the other free, in the state of ether. Besides these changes, however, others take place, such as the deposition of carbon, and the formation of an acid called *sulpho-vinic*, or *oino-thionic*, (οινος, *wine*, θιος, *sulphur*,) formed by the re-action of part of the sulphuric acid on the elements of the spirit; but this is altogether independent of that necessary for the formation of ether itself.

Sulpho-vinic acid, formed during the action of sulphuric acid and alcohol, and noticed particularly by Sertuerner, has, along with *oil of wine*, been lately made the subject of experiment by Mr Hennell, (Lond. Journal, xlii.) According to him, oil of wine is composed of sulphuric acid and olefiant gas, in the proportions of 2 atoms to 8. When heated, half of the latter is disengaged, and sulpho-vinic acid is left, composed of 2 atoms of sulphuric acid, and 4 of olefiant gas, and which is in the

state that it unites with 1 atom of a salifiable base, to form a salt.

Ether does not unite readily with water. When shaken together, it retains 1-10th of its weight of it, and, at the same time, the alcohol which it may contain is removed; and hence a mode of purifying it. For this purpose, they are put together into a bottle, A, and shaken together for some time. On allowing it to stand at rest, the water falls to the bottom, and may be drawn off at B; and by repeating the process several times, pouring in water at C, the ether is obtained pure.



Ether dissolves sulphur and phosphorus. The solution of the latter, when poured over warm water, is luminous in the dark.

The action with chlorine is peculiar. When a teaspoonful of it is thrown into a jar of the gas, previously rendered dry, and the mouth covered with a piece of wood, white fumes instantly appear, and, in the course of a short time, the ether is inflamed.

Ether does not dissolve the fixed alkalies or earths; but it takes up some of the salts, as muriate of gold. Its use in gilding has been noticed, (p. 87.)

It acts with platinum exactly in the same way as alcohol; its vapour keeping the leaf red-hot, and being converted into carbonic acid and water; but besides this, there is the formation of an acid, supposed at one time to be peculiar, but now known to be merely acetic, disguised by the presence of a little carbon and hydrogen, probably in the state of essential oil.

Nitric Ether.

Different methods have been proposed for preparing nitric ether, but they all depend on the decomposition of alcohol by nitric acid. When *nitrous* acid and alcohol are mixed, there is a violent action, accompanied with the disengagement of etherial fumes, and the heat generated is sometimes sufficient to cause the mixture to be inflamed, so that great caution is necessary in conducting

the experiment. In the preparation of ether, equal parts of acid and alcohol are employed, and having put each into a phial, they are to be placed into a cold mixture. The acid is then to be added in small quantities at a time to the alcohol, taking care to cool after each addition. When properly mixed, the whole is poured into a retort, and by the application of a *very slight heat*, as that of a spirit lamp, or warm water bath, the distillation is to be carried on till about half of it comes off, the vapour being condensed in the usual way, but keeping the receiver cool by a freezing mixture *.

During the formation of nitric ether, a considerable quantity of gaseous matter comes off, consisting of carbonic acid, nitrogen, nitric, and nitrous oxids. Thenard, therefore, supposes that both the acid and alcohol are decomposed, part of the oxigen of the former uniting with some of the hydrogen and carbon of the latter, to form carbonic acid and water, while, by the loss of oxigen, the oxids of nitrogen are evolved; at the same time part of the acid, or of its elements, is supposed to unite with those of the spirit, to produce the ether. If this be the case, it is evident that its ingredients are the same as those of sulphuric ether, with the addition of nitrogen. According to Thenard, they are in the proportion of

Carbon,	28.45
Oxigen,	48.52
Hydrogen,	8.54
Nitrogen,	14.49
	100.00

Nitric resembles sulphuric ether in most of its properties, but it is much more volatile, the heat of the hand being sufficient to make it boil. According to Thenard,

* It has been recommended to wait for some days, before proceeding to distil; but there is no necessity for this delay, provided the operator is careful in the application of the heat, which ought to be so regulated, as just to keep the fluid in a state of slight ebullition.

the boiling point is only 70. It is soluble in water, requiring about 48 parts to dissolve it.

When heated in air, it is inflamed, and carbonic acid and water are produced.

When kept for some time, it undergoes decomposition, nitrous acid and the acid of vinegar being formed.

In the Edinburgh Pharmacopœia, a process is given for preparing what is called the *spirit of nitrous ether*, 1 of acid, and 3 of alcohol, being employed instead of equal proportions, as in the preparation of the ether itself. It is probable, that the product of the distillation is merely nitrous ether, with excess of alcohol.

Muriatic Ether.

Muriatic ether may be prepared by the distillation of the acid and alcohol, or by distilling alcohol with muriate of tin: but perhaps the easiest mode of procuring it, is the transmission of a stream of chlorine through alcohol, employing the usual apparatus. The fluid, after being saturated with the gas, is then to be put into a retort, along with chalk, and distilled by a slight heat, by which the superfluous muriatic acid is taken up, and the ether, along with any excess of alcohol, come over together but may be separated by washing with water, as already stated, (p. 154.)

Muriatic ether is also transparent and colourless, volatile and inflammable. According to Robiquet and Colin, (An. de Ch. et de Ph. ii.) it is composed of muriatic acid, with carbon and hydrogen, in the proportion forming olefiant gas.

Ethers with other acids may be formed, but their properties have not been minutely investigated.

Acetous Fermentation.

Every substance which undergoes the vinous, may be made to pass into the acetous fermentation; there are, besides, many that seem at once to run into the latter, particularly those which contain much mucilage, and

little sugar. Alcohol, when pure, does not undergo acetous fermentation, but if it contain vegetable matter, a change takes place in it; hence the reason why wines become sour, and why weak do so sooner than strong ones, the former having little alcohol, and a good deal of vegetable matter, while the reverse is the case with the latter. Wine which has been deprived of its vegetable matter by clarification does not become sour, but if some of this be put in, acetous fermentation commences under favourable circumstances. Certain things are necessary for this change taking place. The fluid must be kept at a particular temperature; between 60 and 80 is the best, but if it fall below 50, the fermentation stops. It must also be exposed to the air, otherwise it does not take place; hence the reason why spirituous and malt liquors do not become sour, when kept in well corked bottles. The presence of some substance that acts as a ferment is also necessary, which may be either yeast, or the sediment from a fluid that has already undergone the process.

It appears that sugar is the essential ingredient in those fluids that undergo acetous fermentation, and the quantity of vinegar formed is to a certain degree in proportion to it; thus, 7 of water and 1 of sugar, with a little yeast, form vinegar: if more be used, part is left undecomposed.

In those countries where grapes abound, vinegar is generally prepared from wine. In this island it is usually obtained from grain. That from the former is reckoned not only the best, but least liable to decay, for, when prepared from the latter, it contains vegetable matter, which causes it to become mouldy; but this may in a great measure be prevented by boiling, by which the substance in solution is coagulated, and may be removed.

In manufacturing vinegar from malt, a *wort* made in the usual way, by mashing it with water, after being mixed with yeast, which is put into barrels, and kept at a moderate heat for some weeks, during which it becomes sour, having previously passed through the vinous stage, and afterwards run into the second or acetous. Vinegar

is often made on a small scale, for which purpose sugar, or fruit, as currants or gooseberries, are mixed with water, to which there is added a little yeast. The whole is put into a cask, and kept in a warm room till it is known by the taste to have become sufficiently sour, after which it is bottled and corked, to prevent it from becoming mouldy.

Vinegar, as usually obtained, is of a pale brown colour, having a pleasant odour and a sour taste. It contains water, glutinous, mucilaginous, and saccharine matter, and an acid not yet described, called *acetic*. *(See Vegetable Acids.)*

During the progress of acetous fermentation, carbonic acid gas is disengaged, and it has been found that the oxigen of the atmosphere is at the same time consumed; from which it has been inferred, that the carbon existing in the acid is emitted from the fluid undergoing the change, and unites with the oxigen of the air; and this seems strengthened by the fact, that the gaseous matter produced is equal in volume to the oxigen consumed. The particular changes, however, that take place, by which alcohol or vegetable matter is converted to vinegar, have not yet been ascertained.

Vinegar is now manufactured on a large scale by subjecting wood to distillation, a process much practised for procuring that employed in the arts, as in the preparation of the different salts containing it. For this purpose, wood is put into large cast iron cylinders, and heated to redness, by which its elements are made to enter into a new state of union, and generate vinegar, which passes off in vapour, and is condensed in receivers; it is not, however, pure, it is mixed with tarry matter, but from which it is easily freed by repeated distillation. In this state it is called *pyroligneous acid*, (πυρ, fire, *lignum*, wood.) It is then a transparent colourless fluid, having a much sourer taste, but by no means the pleasant flavour of common vinegar.

Putrefaction.

Almost every kind of vegetable matter is liable to undergo putrefaction; certain circumstances are, however, necessary for the commencement of this process, as the presence of moisture and a proper heat. The substance first acquires a mould on its surface, it emits a disagreeable smell, and in the course of time is almost entirely consumed. That moisture is necessary for the matter to putrefy is evident, for if it be subjected to a high temperature, which drives off the watery part, it does not afterwards suffer any change. The temperature to which it should be subjected to make it undergo the putrefactive process, must therefore be such as will not expel the moisture, and the admission of air also favours the decomposition; the ingredients being dissipated in the form of new aeriform fluids. Many substances, however, particularly those in which there is a large proportion of charcoal, are not consumed; there remains a black matter called *vegetable mould*, which, when excluded from the air, does not putrefy, but soon does so when exposed to it.

Vegetable mould forms a principal part of the soil, and contributes in no small degree, when properly treated, to vegetation, for which purpose the earth requires to be frequently turned up, to expose the mould, and allow putrefaction to go on, by which the matter probably passes into that state, that it is easily dissolved by water, and is thus taken up by plants, and affords them nourishment. When this is not done, and when the vegetable matter mixed with the soil is in large quantity, it collects, and forms *peat* and *morass*.

SECTION II.

VEGETABLE PRINCIPLES.

Sugar.

This substance, so familiar from its general use, has been long known, but it was not till after the discovery of America that it was introduced to Europe as an article of food. It is generally obtained from the juice of the sugar cane, consisting of water holding sugar dissolved in it, a mucilaginous matter, and an essential oil, and along with these there are pieces of the cane and leaf, and other impurities, all of which it is the object of the processes to which it is subjected to remove. The juice extracted by passing the cane between rollers, after being brought to a boiling heat, is mixed with slaked lime, with the view of neutralizing any acid that may exist in it, after which the clear fluid is drawn off into evaporating basins, and evaporated as quickly as possible, the scum being removed as it rises to the surface, and the boiling continued, till it becomes of such consistence that it will crystallize on cooling. It is then poured into wooden troughs, where it deposits small crystals, surrounded by a brownish fluid. The crystalline mass thus obtained is put into hogsheads, in the bottom of which there are a number

of small holes, and placed over a large cistern, which is to collect the *molasses* or *treacle* that drops through; after it has dripped for two or three weeks, it is nearly dry, in which state it is imported to this country, under the name of *muscovado* or *raw sugar*.

Raw sugar contains impurities, from which it is freed by the process of refining, practised almost always in Europe. For this purpose, it is dissolved in lime water, and after being brought to a boiling heat, has bullock's blood mixed with it, which being instantly coagulated, entangles the foreign matter, and is skimmed off as it rises to the surface; at the same time, the lime neutralizes any acid that may have been left in the preceding process. After this it is filtered through blankets, and boiled down to the proper consistence, and, when cold, is poured into unglazed earthen vessels, of a conical shape, with their smaller ends down, and having a hole in them, stopped with a plug of clay, but which, after the evaporated juice has become solid, is removed, and the unconsolidated part is allowed to drip through for some hours; a piece of wet clay is then put on the upper or broad end, the water of which passes through the sugar, and carries out the impurities, the process being repeated till the whole is removed. When the claying is finished, the sugar is hardened, by heating it in a stove-room, and is then called *loaf* or *refined* sugar. It sometimes also undergoes a second, or even a third purification, and is then called *double* or *triple* refined.

Sugar, when pure, is white, and when crystallized, is semi-transparent. Its specific gravity, according to Hassenfratz, is 1100. When two pieces of it are rubbed together in the dark, they become luminous at the point of contact.

When subjected to heat in close vessels, carbonic acid, carburetted hydrogen, and a weak acidulous fluid, are given off, and charcoal is left; so that its component parts are the same as those existing in vegetable matter in general; but different statements have been given of its composition, the analysis having been

conducted by heating it with chlorate of potass, and with oxid of copper. The following are the results of

	Thenard.	Berzelius.	Prout.
carbon,	42.47	44.2	39.99
oxigen,	50.63	49.	53.33
hydrogen,	6.9	6.8	6.66
	10.000	100.0	99.98

We may consider that of Prout as correct, because it is the only one that accords with the atomic doctrine. If so, the proportions are,

carbon,	1 atom,	7.5
oxigen,	1 atom,	10.
hydrogen,	1 atom,	1.25
The atom of sugar being		18.75

Sugar is not altered by exposure to a dry atmosphere; but in a damp one it absorbs moisture. When heated in air, it fuses and swells; and if the temperature be high, takes fire, and burns with considerable violence.

Sugar is soluble in water, requiring only its own weight for solution. At a boiling heat, the water of crystallization is sufficient to dissolve it. The solution, when strong, is thick and viscid, and is called *syrup*.

Sugar is decomposed by acids; the results differing according to that employed. When nitric acid is poured on it, there is an effervescence, and disengagement of nitric oxid, and hence one method of preparing this gas; but it is necessary to use it diluted with an equal quantity of water, to moderate the action. When the gas ceases to come off, the fluid in the retort gradually deposits crystals of *oxalic acid*, and by the evaporation of the supernatant liquor, *malic acid* is obtained.

Sugar unites with the alkalies, and the taste is in a great measure destroyed; but by the addition of an acid, the latter may be neutralized, and the former obtained, apparently unchanged in its properties.

Sugar is soluble in alcohol, but not in large quantity. According to Lewis, it requires 12, and according to

Maargraff, 16 parts, at a boiling heat, to dissolve it; the solution, when its temperature falls, depositing crystals.

Sugar is obtained from other sources than those already mentioned; beet-root, carrots, turnips, parsnips, figs, and grapes, yield it, and it is also procured, in considerable quantity, from the mapple-tree.

Sugar may be formed, also, by the action of diluted sulphuric acid on starch, and other vegetable substances, and it is produced, in considerable quantity, during the process of malting. It is a remarkable fact, also, that it is formed during a certain state of the human body, as in those labouring under diabetes mellites, the urine yielding, by evaporation, the saccharine principle similar in its properties to common sugar.

The uses of sugar, as an article of food, are well known. It is employed largely as an antiseptic, as in making jellies and conserves. It enters into the composition of some varnishes, and it is an ingredient of ink, and of those pigments which have a fine lustre. It has lately been recommended by M'Culloch for preserving fish; for which purpose, the fish is merely rubbed over with it, and then hung up to dry.

Gum.

Though there are many varieties of gum, the difference seems to depend, in a great measure, on foreign admixture. That yielded by the *acacia arabica*, called *gum arabic*, is the purest, and from it, the properties of gum have been ascertained. It exudes in a liquid state from the trees, either spontaneously or from incisions made in the bark, and becomes hard by exposure to air.

It is usually in small irregularly formed pieces of pale yellowish and brown colour, having a slight degree of transparency and lustre. It is brittle, when cold, so that it can be easily reduced to powder. Its sp. gr. varies from 1316 to 1490.

When exposed to heat in air, it softens and swells, but does not melt, and if the heat be continued, a gaseous

fluid is disengaged, and the whole of it is consumed, except a minute quantity of white ashes, consisting of carbonate and phosphate of lime. When heated in a retort, the products are water, carbonic acid, and carburetted hydrogen, leaving charcoal and the earthy salts.

We are indebted to Thenard and Berzelius for the most accurate analysis of gum.

	Thenard.	Berzelius.
carbon,	42.23	41.9
oxigen,	50.84	51.3
hydrogen,	6.93	6.8

That of Berzelius is perhaps nearest the truth, for by a very slight alteration the ingredients will be found to be in atomic proportion. They are probably,

carbon,	39.47,	or	5 atoms	= 37.5
oxigen,	52.63,	or	5 do	= 50.
hydrogen,	7.9,	or	6 do	= 7.5
	100.00			

if so, the atomic weight of gum is 95.

Gum is very soluble in water; the solution called *mucilage* is viscid, and when the gum is in considerable quantity, is thick, and adhesive. When exposed to the air, it acquires a mould on its surface, but in well corked phials, it may be kept long without undergoing any change; even in these, however, in the course of time, a little acetic acid is generated. Chlorine passed through the solution causes the formation of *citric* acid.

The diluted acids dissolve gum, but when concentrated, they decompose it. When nitric acid is poured on it, an acid called *mucic* is formed, but by the continuance of the action, oxalic and malic are produced.

Sulphuric acid causes gum to become black from the disengagement of part of its carbon, at the same time water and acetic acid are generated.

The alkalies and alkaline earths dissolve it, and on the addition of an acid it is deposited unchanged.

Of the earths, silica seems to act most easily with it. When silicated potass is added to very weak mucilage, a

white precipitate appears; hence the use of this re-agent as a test of gum.

Gum has no action with metals. It produces changes, however, on some of the metallic oxids. From solution of nitrate of mercury mucilage throws down a white, from per-sulphate of iron a brown powder, but the salt that acts most easily is sub-acetate of lead, which occasions a white curdy precipitate; and hence also the use of the solution as a test of gum.

When mucilage is added to salts of antimony, bismuth, and tin, there is no precipitation, shewing that gum has the power of keeping their oxids in solution, for water alone causes the decomposition of these metallic salts.

It is insoluble in alcohol; hence, when alcohol is mixed with mucilage, the gum is deposited, owing to the strong attraction existing between the fluids.

It combines with sugar. The fluid obtained by boiling them together in water, yields, on evaporation, a substance, which, when treated with alcohol, leaves gum, and gives an alcoholic solution of sugar, but apparently in combination with some of the gum.

Besides gum arabic, there are others which, though they differ a little from it, yet resemble it in most of their properties. These are, cherry tree gum, and the mucilaginous matter obtained by decoction from lintseed, marsh mallow, bulbous roots, some species of fuci, and lichens, and many others.

The substance called *tragacanth* is different in many respects from common gum. When mixed with cold water, it softens, and swells considerably, but is not dissolved. Warm water seems to dissolve a little of it, but the solution does not yield a precipitate on the addition of silicated potass. The mucilaginous matter formed by the action of water is not adhesive like that of gum, for pieces of paper besmeared with it do not adhere. It is supposed that tragacanth contains a peculiar principle called *cerasin*.

Gum is also formed by the action of certain re-agents on vegetable matter. When the dried sawings of the *horn beam* are boiled with diluted sulphuric acid, sulphurous acid is disengaged, the mixture becomes black, but after filtration and neutralization of the excess of acid by lime, yields, when evaporated, a substance possessing all the properties of gum. *Hemp cloth*, also, when treated in the same way, affords it, which, when boiled with sulphuric acid, is converted to sugar and a peculiar acid. Hence one of the processes alluded to (p. 163.) for procuring sugar. For this purpose 4 of rags are triturated with 34 of acid; the solution, after being diluted, is boiled, then saturated by carbonate of lime, filtered, and evaporated, by which the saccharine matter is obtained.

Gum is used chiefly for suspending substances in water; hence its use in dyeing, and in ink-making, and, for the same reason, it is employed in medicine, with the view of keeping oily or resinous matter in suspension in water.

Fecula or Starch.

When any farinaceous substance, as wheaten flour, is put into a muslin bag, and subjected to the action of a stream of water, it is separated into two parts; a tough whitish substance, which remains in the cloth, and a white powder suspended in the fluid, and deposited when kept at rest. The former is called *gluten*, the latter *fecula* or *starch*. Besides these, there is a little mucilaginous matter held in solution.

Fecula, as thus obtained, is a light white powder, destitute of taste and smell. When heated, it becomes soft, and swells, and if the temperature be high, it takes fire, but does not burn with much violence. When heated till it begins to turn yellow, its properties are completely altered; it is changed to a substance resembling gum in some of its properties, being soluble in cold water, and giving a mucilaginous solution. It differs from it, however, in not yielding *mucic acid*, when treated with nitric acid.

This substance is now used by calico printers, under the name of *British gum.* (An. of Ph. V. xvi.)

When fecula is heated in a retort, it yields the usual products along with a little acid, at one time called pyromucous, but now known to be merely acetic, disguised by empyreumatic oil, so that the ingredients are the same as those of the principles already described. The latest analyses are by Gay Lussac and Berzelius.

	Gay Lussac.	Berzelius.
carbon,	43.55	43.481
oxigen,	49.68	48.455
hydrogen,	6.77	7.064

Fecula is insoluble in cold water, but warm water easily dissolves it, and if the quantity be considerable, it forms a thick transparent solution, which gelatinizes on cooling. If little starch be employed, the water, when cold, still holds part of it dissolved, but gradually deposits it. The solution, when kept for some time, acquires a mould on its surface, and becomes sour, and according to Saussure, (Ph. Tr. 1809.) is completely altered in its properties, being converted to sugar, gum, amyline, starchy lignin, and lignin mixed with charcoal, the gum being similar to that obtained from starch, by the application of heat.

Amyline is procured from the decomposed starch, by first washing it with cold, and then dissolving the residue in boiling water. The solution is transparent and colourless, and on evaporation yields a semi-transparent matter, insoluble in alcohol, but soluble in water. It is precipitated by sub-acetate of lead, and it gives a blue precipitate with iodine, a property possessed also by starch.

Starchy lignin is obtained from the insoluble residue of the former process, by washing it with alcohol and diluted sulphuric acid, and then with a weak solution of potassa, the last of which dissolves it. By the addition

of sulphuric acid, it is precipitated of a dark colour, and, like amyline, becomes blue when mixed with iodine.

Fecula unites very easily with iodine, and forms with it a compound of a blue colour called *iodid*, or *ioduret of starch*. It may be formed by triturating them together, or by mixing their solutions, avoiding an excess of starch, which re-dissolves the precipitate. From the ease with which iodine and starch unite, they are employed as tests of each other. *(See Iodine.)*

The acids act on starch in very nearly the same way as on gum. Nitric, either concentrated or diluted, slowly dissolves it in the cold; but when heat is applied, there is a decomposition, and formation of oxalic acid, nitrous acid fumes being given off.

When thrown into strong sulphuric acid, it is charred, and when the quantity of starch is considerable, the mixture becomes almost solid, from the deposition of carbon. When the acid is diluted, the fecula is dissolved, and by particular management may be converted to sugar, as was first noticed by Kirchoff, a Russian chemist, when endeavouring to change it to gum. The process consists in boiling it for about 36 hours, in four times its weight of water, acidulated with about 100th part of sulphuric acid, adding water occasionally, to compensate for loss by evaporation. After the boiling is finished, the acid is neutralized by lime, the solution filtered and evaporated, by which a saccharine mass resembling common brown sugar is obtained, and which undergoes vinous fermentation, and yields a spirituous fluid without the addition of yeast, in this respect differing from common sugar, (Nich. Journ. 33.) If the process be stopped before the sugar is formed, a considerable quantity of gum is found in the solution.

This process has been investigated by Saussure, who has shewn that the sugar obtained is by about 1-10th greater in weight than the starch employed; and De la Rive has proved, that the air has no share whatever in its formation, the action going on in close vessels, and that the sulphuric acid is not changed in its properties. From

the analysis by Saussure, it appears that in the product there is a larger proportion of oxigen and hydrogen than in the fecula itself, from which he has concluded, that to convert starch to sugar, all that is necessary is to cause it to combine with water or with its ingredients, in such proportion as to form it.

The alkalies dissolve fecula, and form a transparent solution, from which acids precipitate it apparently unchanged in its properties.

Watery solution of starch is not affected by that of lime, strontin, or silicated potass, but baryta water occasions a white flaky precipitate.

It is precipitated also by sub-acetate of lead, but not by any other metallic salt. When starch and sub-nitrate of lead are digested together, they combine, and form a compound, which, according to Berzelius, is composed of 72 fecula, 28 oxid of lead.

Fecula is insoluble in alcohol and in ether; of course, its watery solution is decomposed by the addition of alcohol.

Fecula is contained in a great many vegetables, particularly in the seeds and roots of those employed as food, as in the different kinds of grain, rice, peas, beans, and potatoes; the pith of several trees also contains it. Sago prepared from the pith of some palm-trees, salop from the roots of the orchis, cassava from the jatropha manihat, and arrow-root from the maranta arundinacea, are composed almost entirely of it. All of these are prepared in the usual way, by subjecting the substances from which they are procured to the action of water, as already described in the process for obtaining fecula from flour.

Fecula is employed in baking, *(see gluten,)* and in giving stiffness to cloth, for which purpose *starch*, either from wheaten flour or from potatoes, is generally used. In preparing starch, wheat, after being bruised, is kept in cold water for about a fortnight, where it undergoes a slight fermentation, generating a little acetic acid, by which the impurities are dissolved. It is then

mixed with water, till the pulpy matter becomes so thin, that it can be passed through a hair sieve, by which the husks are removed, and the filtered fluid allowed to remain at rest, till the starch is deposited. It is not, however, pure; it is therefore again treated in the same way, and afterwards put into boxes, having the bottoms perforated, and lined with linen cloth, through which the water passes, and leaves the starch behind. When it has become of sufficient consistence, it is cut into cakes, and dried by a stove, during which they crack, and form the small irregular pieces.

The process followed in the preparation of starch from potatoes, is nearly the same; indeed, all that is necessary is, after removing the skin, to bruise them, and, having put them into a coarse bag, to knead them in water, by which the fecula passes through, and is obtained by subsidence.

Gluten.

In the preparation of fecula from grain, the residue left in the bag is gluten. It is a soft viscid substance, tenacious, elastic, and very adhesive, having a fibrous texture, and a faint peculiar odour.

When exposed to a dry air, it acquires a brownish crust on its surface, and is covered with a thin film of an oily-looking matter, and ultimately becomes hard and brittle, resembling a piece of glue. In a moist atmosphere it swells, and undergoes putrefaction, emitting an offensive odour, and, at the same time, acetic acid and ammonia are formed.

When subjected to heat in air, it is inflamed, giving off the smell of burning feathers. In close vessels it yields carburetted hydrogen, an empyreumatic oil, and *carbonate of ammonia*, leaving charcoal in the retort.

When gluten is kept in water, the fluid becomes opake, and films are suspended in it, which may be removed by filtration; but it still holds dissolved a substance precipitated by heat, by chlorine, and by some

metallic salts. This is supposed to be merely gluten kept dissolved by a little acetic acid, generated during the decomposition. When, instead of immersing gluten in water, it is kept merely moistened, it swells, emits an offensive odour, and carbonic acid and carburetted hydrogen are disengaged.

These changes shew, that, like other vegetable bodies, gluten contains oxigen, hydrogen, and carbon; but besides the usual products, it yields also *ammonia*, so that it must, in addition to these, contain nitrogen, in this respect differing from the principles already described, but no particular analysis has yet been made of it.

The acids act on gluten, the action differing according to the acid, and its state of dilution. When nitric acid is poured on it, and heat applied, it is slowly dissolved, at the same time, however, undergoing decomposition; for if the action be carried on in a retort, nitrogen gas is given off. The fluid left contains oxalic and malic acids.

Sulphuric acid chars it, and carburetted hydrogen, carbonate of ammonia, and acetic acid, are formed.

Weak alkaline fluids dissolve it by the aid of heat, and from the solution a precipitate is thrown down, by the addition of an acid, but which is not gluten. If a strong solution of alkali be employed, ammonia is formed, and a soapy compound is produced.

The action of metallic salts with gluten has been but little examined. According to Bostock, water in which it has been immersed, affords a precipitate with acetate of lead and nitrate of mercury.

When gluten is kneaded with successive portions of alcohol, till the fluid poured off ceases to become turbid on the addition of water, it is, according to Taddey (An. of Ph. xv.), separated into two principles, one of which only is taken up by the spirit. That dissolved he has called *gliadine*, (from γλια, gluten), the other *zimome*, (from ζυμη, a ferment.)

Gliadine is obtained by the evaporation of the alcoholic solution. It is a brittle semi-transparent substance, of a yellowish colour, and having the odour of honey-comb. It is

softened, but not dissolved, by cold water. When heated, it burns with a lively flame, leaving charcoal. It is dissolved by acids, and concentrated alkaline fluids. Its alcoholic solution becomes milky on the addition of water, and the alkaline carbonates precipitate white flakes. It undergoes, of itself, vinous fermentation, and excites it in other bodies.

Zimome, the insoluble matter left after removing the gliadine from gluten, is a hard, tough substance, of an ash gray colour, but becoming brown on exposure to air. When thrown on hot coals, it emits the odour of burning horn. It is dissolved by the acids, and with potassa forms a kind of soap. It excites various kinds of fermentation according to the vegetable matter with which it is mixed. When treated with gum guiacum, it assumes a rich blue colour, and hence this is used as a test of it, and by which it may be discovered in other vegetables than gluten. For the success of this process, however, the presence of air is necessary, the action seeming to depend on the absorption of oxigen.

When describing the phenomena of fermentation, it was mentioned that the action of a substance called a ferment is necessary, and which, it is supposed by some, is similar in many respects to vegetable gluten. *Artificial ferment* may be prepared by causing any substance, such as grain, to undergo vinous fermentation; by which a frothy mater rises to the surface, and is skimmed off. This is sold under the name of *yeast* or *barm*, and is now employed with the view of exciting fermentation, particularly by bakers. It has been found to have many of the properties of gluten; and that gluten is, or at least contains, the principle which excites fermentation, seems to be proved by the experiments of Taddey, just related.

Gluten is contained in greatest quantity in wheat, and from which it is usually obtained. According to Beccaria, wheaten flour contains about 1-12th, and if we take into account the water imbibed during its preparation, it yields about 1–4th of its weight of it. Davy, however, states, that the proportion varies in different kinds,

the North American yielding most. In his experiments, it was from 19 to 24 per cent.

Gluten is found in other substances, though in small quantity, as in barley, rye, peas, beans, chesnuts, and many others. It does not, however, exist in potatoes, which yield such a large proportion of *fecula*.

Gluten, from its close resemblance to the principles of the animal kingdom, is supposed to be very nutritious. From the changes which it so easily excites in other bodies, it is employed largely in brewing and distilling, (*see p.* 138, 140.) and also in the making of *bread*.

The substances used in baking are, wheaten flour, water, yeast, and salt, the proportions varying in different places, according to the temperature, the quality of the flour, and the quantity to be baked. The yeast necessary for a sack, (32 pecks,) is in general about 3 pints (English) and 4 pints of water to each peck. The proportion of salt depends in a great measure on the taste of the baker. In general the yeast, with the salt, and about half of the water and flour, are first mixed in a wooden trough, and kept in a warm place, during which the glutinous principle in the flour, being acted on by the yeast, begins to undergo fermentation, becoming sweetish, and disengaging carbonic acid gas, the greater part of which, owing to the adhesive quality of the mixture, is prevented from escaping; it therefore causes it to swell, and become spongy, hence the product is called by bakers a *sponge*. Having been kept for about 10 or 12 hours in this situation, it is put into a trough, and mixed with the remainder of the flour and water, by which the fermentation is stopped, but it again very soon commences. The substance thus formed, called *dough*, is kept in the trough for about an hour, during which the fermentation proceeds, carbonic acid gas is again generated, and being retained, causes the mixture to swell considerably; but at this stage, it is necessary to put a stop to the process, otherwise the product would become sour. The dough is therefore cut into loaves of the requisite size, and exposed to heat in an oven, for

about an hour, by which part of the moisture is expelled, and the fermentation ceases.

The late experiments of Dr Colquhoun, (An. of Ph. N. S. xii.) prove satisfactorily, that the changes that ensue during the conversion of flour into bread, are the same as those produced by vinous fermentation; indeed, from bread alcohol can be obtained by distillation, and hence it is, that if the process be carried on too long, the acetous stage is apt to commence.

Those substances which have little or no gluten, do not answer for making bread, because, as it is it that occasions the fermentation, and consequent disengagement of gas, the product is not at all porous. A certain degree of porosity may, however, be communicated, by mixing these with others that contain it.

Besides the substances already described as existing in grain, another has been mentioned by Proust, called *hordein*, and which can be obtained merely by washing off the fecula from starch, by means of boiling water, (An. de Ch. et de Ph. v.) It is this which is supposed by him to undergo a change during the process of malting, and give rise to the formation of saccharine matter; but besides it, the gluten is also changed, as the following table of the composition of grain, before and after malting, will shew.

	in 100 of barley.	in 100 of malt.
resin,	1	1
gum,	4	15
sugar,	5	15
starch,	32	56
gluten,	3	1
hordein,	55	12

Wax.

Wax, though prepared by bees, is undoubtedly of vegetable origin, and seems to be formed by some change which saccharine matter undergoes. As usually procured, it has a yellowish colour, and a pleasant odour, but

it may be deprived of these by the process of purification, consisting merely in exposing it, in thin plates, to the action of the air and sunshine, by which it is completely bleached. In this state, its specific gravity is about 960. When heated, it melts at about 155; and before it becomes fluid, passes through different degrees of consistence. When the temperature to which it is exposed is high, it takes fire, and burns with a bright flame, yielding carbonic acid and water.

Lavoisier endeavoured in this way to find its composition, and Gay Lussac and Thenard, and also Dr Ure, in the result of whose experiments more reliance is to be placed, have analysed it by means of chlorate of potass, and peroxid of copper. The following is the composition given by them.

	Thenard.	Ure.		atoms.		
carbon,	81.784	80.69,	or	13	=	80.41
oxigen,	5.544	7.94,	-	1	=	8.26
hydrogen,	12.672	11.37,	-	11	=	11.33

Dr Ure thinks it not improbable, that it may contain 1 atom more of hydrogen than has yet been detected in it; and if so, its ingredients will be in proportions, to form 12 atoms olefiant gas, and 1 of carbonic oxid.

Wax is insoluble in water.

The acids act with little energy on it.

The fixed alkalies dissolve it, forming saponaceous compounds, which are insoluble in cold, but soluble in warm water, and from the solution the acids precipitate the wax, little, if at all, altered in its properties.

Water of ammonia, when slightly heated, also dissolves wax, forming a kind of emulsion, from which the greater part of the wax separates as it cools.

Wax is insoluble in cold, but soluble in warm alcohol, which takes up about 1-20th of its weight. The solution is transparent and colourless, is decomposed by water, and deposits the greater part of the wax as its temperature falls.

When wax is digested in a large quantity of alcohol, it is, according to Dr John, separated into two substances,

which he calls *cerin* and *myricin*, the former being taken up, while the latter remains undissolved.

Cerin is of the consistence of wax, and specific gravity 1000; it melts at a temperature between 108 and 140. It is insoluble in water; but alcohol and ether, by the aid of heat, dissolve it.

Myricin is of sp. gr. 900. Its consistence and melting point are nearly the same as those of cerin. It is insoluble in water, alcohol, and ether.

Ether does not dissolve wax in the cold; but when the temperature is raised, it takes up about a half of its weight of it, the greater part of which it deposits on cooling.

Besides bees wax, there are others procured directly from vegetables themselves, of which the most common is *myrtle wax*, the produce of the myrica cerifera. To obtain it, the berries are bruised and boiled in water, by which the wax is melted, and, collecting on the surface, is skimmed off, and instantly passed through cloth, to free it from impurities. It is then bleached in the same way as common wax.

Myrtle wax, though it differs slightly in its colour and fusibility from common wax, resembles it in its other properties.

Wax is likewise found on the upper surface of the leaves of some trees; and it exists also in the substance called *white lac.*

Wax is principally employed for affording light. The superiority of wax over tallow candles, depends on the former not being so fusible, and hence requiring a smaller wick. In the latter, the matter melted by the heat is much greater; a large wick is therefore necessary for drawing it up, which being placed in the centre of the flame, is excluded from the air, and is not consumed; unless, therefore, it is frequently removed, it obstructs a great deal of the light. The small wick of a wax candle, on the contrary, is sufficient to draw up the melted matter; it obstructs less light, and, though excluded from the air by being surrounded by the flame, yet, when

it becomes long, it bends, and thus the end getting without it, is consumed, so that it does not require to be snuffed.

Wax is likewise employed in taking casts and moulds, for which, from its softness when a little heated, it is well adapted. It is also a principal ingredient in some kinds of luting, *(see Resin.)*

Oils.

Oils are divided into two kinds, the *fixed* or *unctuous*, and the *volatile* or *essential*. Before proceeding to describe the properties of these, it may be here remarked, that oleaginous matter exists also in the animal kingdom, the general properties of which are the same as those from vegetables; so that the account here to be given will apply to both.

Fixed or Unctuous Oils.

The fixed oils, of which there is an immense variety, are generally fluid, but of a thickish consistence, and unctuous feel, leaving a greasy stain on paper, and which cannot be removed by heat alone. They are sometimes colourless; occasionally of a greenish or yellowish colour; and, when pure, semi-transparent, and with very little smell. They differ, but not much, from each other in specific gravity. Olive oil is 913; palm oil 968; the others being intermediate.

They do not boil till heated to about 600, at which they pass into vapour, but not without suffering a slight decomposition; for, during the ebullition, water, acetic acid, and carburetted hydrogen, are given off; a little carbon is deposited, and the residual fluid is of less density and less viscid than before.

When oils are kept for some time, they become rancid; they thicken, acquire a sour taste, and the property of reddening vegetable blues, occasioned, according to Scheele, by the decomposition of mucilaginous matter, which they always contain.

When oil is exposed to air, it absorbs oxigen, and gradually increases in consistence, till at last it becomes solid. Some oils, when dry, are opake, others are transparent, and, if spread thin on paper, acquire a resinous lustre. To the former, called *fat* oils, belong those from lintseed, nuts, poppies, and hempseed; to the latter, termed *drying*, olive oil, oil of almonds and of rapeseed.

That the thickening of oil is owing to the absorption of oxigen, has been proved by numerous experiments; lintseed oil, when spread on paper, having been found to imbibe not less than twelve times its weight of it. Under certain circumstances the absorption goes on so rapidly, that the heat generated is sufficient to cause combustion. When, for instance, tow or cloth is soaked in oil, and heaped together, its temperature very soon rises, and it at last takes fire. Hence the necessity of being cautious in throwing aside tow or other matter which has been used for cleaning the oily parts of machinery, as instances have occurred of fires being occasioned in this way.

When oil is heated to a proper temperature in air, it is kindled, and burns with a yellow flame, emitting the usual products, carbonic acid and water. For complete combustion, the heat must be more than sufficient to convert it to vapour; and, for the purposes to which it is usually applied, it is in general accomplished by means of cotton, the temperature excited by the combustion of which sets it on fire. *(See Combustion.)*

When the oil is passed in vapour through incandescent tubes, it is decomposed, the product consisting of hydro-carbons, with a little carbonic acid and water.

All of these experiments prove, that oil contains the usual ingredients; and the analysis of olive oil by Guy Lussac and Thenard, shews it to be composed of

carbon,	77.213	10 atoms
oxigen,	9.427	probably 1 atom
hydrogen,	13.360	11 atoms.

Now, if we suppose that the oxigen is in union with the

hydrogen, composing water, the remaining ingredients are in proportions to form olefiant gas; so that the composition may therefore be thus stated;

olefiant gas, 10 atoms
water, 1 atom.

Oil is insoluble in water. When mixed with it they seem to unite, but, when kept at rest, they soon separate, each assuming the situation allotted to it by its specific gravity.

Oil dissolves sulphur and phosphorus, forming a solution from which the inflammables are deposited in the crystalline form, by evaporation. That of the latter is luminous in the dark, when exposed to the air; and hence it may be rubbed on the hands or face, to cause them to become phosphorescent, and without injury.

Oil is decomposed by acids, the results differing according to that used. By the action of nitric acid, a whitish substance is formed, from which, if heat be applied, nitric oxid is disengaged. Sulphuric acid instantly renders oil black, from the deposition of charcoal, and sulphurous acid is set free.

Alkalies act very easily with oil, and the action is important, as by their union the useful article soap is formed, the quality of which differs according to the alkali it contains. When solution of any alkali and oil are mixed, a saponaceous compound is formed, which is held in solution by the water; and the same also occurs even with the alkaline carbonates.

The substances used in the manufacture of soap, vary according to the kind to be made. For the *finer white* soap, olive oil and soda are employed. *Common* white soap is prepared from tallow and soda, instead of which, pot-ashes and sea salt are sometimes used; and yellow soap is made of these and resin. When oil is mixed with soda, the soap is in general hard, but with potass it is soft; if, however, sea salt be added to the latter during its preparation, it makes it of the same hardness as the other, the potass uniting with the muriatic acid of the salt, and setting free the soda, which acts on the oil.

When, then, owing to the expense of kelp and barilla, or to other circumstances, soda cannot be procured, potass and sea salt are employed.

In making common soap, the alkaline matter, say kelp or barilla, is dissolved in water, and mixed with lime, which, by uniting with the carbonic acid, and forming an insoluble compound, sets the soda free; the solution, after being drawn off, is evaporated to the proper consistence, in which state it is called a *ley*, and is ready for receiving the oil. The tallow, after being melted, is poured into it, and the whole is boiled so as to cause them to unite. The fire is then extinguished, and the materials left at rest for some time. Sea salt is next added, and heat again applied, and more alkaline solution put in; and in this way the process is carried on, till the whole of the materials is used, the watery part being drawn off as it is separated from the soap; at the same time the boiling is continued, till it becomes of the proper consistence, after which it is poured into the frames to harden.

It has been said that sea salt acts, when potass is used, by its being decomposed, and liberating soda; it serves, however, another purpose. It is supposed to combine with the watery part, and remove it from the soap, which thus becomes sooner hard, and consequently the process is considerably shortened. If potass be used without the addition of sea salt, the soap formed does not become hard; and hence the method of making *soft soap*. The oil generally employed is that of lintseed, hemp, or rape. It is mixed with a strong alkaline solution, obtained from potashes and lime, and after being thoroughly incorporated, the mixture is boiled till the soap becomes of the proper consistence.

Soft soap is usually of a brown colour, is much stronger and more acrid than the other. When well made, it is of the consistence of thick paste, and should be entirely soluble in water, forming a white froth. It is employed chiefly for scouring woollen stuffs.

Common *yellow soap* is made with the solution pro-

cured from kelp or barilla, and tallow, to which, after they are sufficiently mixed, melted resin, and occasionally a little palm oil, is added. The subsequent parts of the process are the same as has been already described.

Soap prepared by any of these processes, does not possess either the corrosive quality of the alkali, nor the greasiness of the oil; water, when pure, dissolves it, but if it contain an earthy salt in solution, it is not dissolved, but decomposed. Hence the cause of the *hardness* of water, which is owing in general to the presence of a salt of lime, by which the earth unites with the oil of the soap, and forms an insoluble compound. If we attempt to dissolve it in hard water, white flocculi are formed, and it has a disagreeable feel; hard water does not therefore answer for washing with. The hardness of water may in a great measure be removed, by boiling it for some time, and by the addition of carbonate of an alkali, which, by the decomposition of the earthy salt, prevents its action on the soap; but even with these additions, it is not so good as soft water.

The nature of the action by which soap is formed, was by no means understood till Chevreuil commenced his investigation of oils, (An. de Chem. xciv.) He found that they contain two distinct substances, possessed of peculiar properties. One of these he has called *stearin*, (from στεαρ, suet,) the other *elain*, (from ελαιον, oil.)

Stearin is obtained most easily by the process recommended by Braconnot, (An. de Ch. et de Ph. 11.) which consists in congealing the oil by cold, and keeping it between several folds of bibulous paper, by which the elain is removed. It is a soft white substance resembling wax, destitute of taste and smell. Its point of liquefaction differs according to the matter from which it is procured. That from common tallow melts at 109, and on cooling crystallizes. When mixed with an alkali, it forms soap.

It is soluble in alcohol when warm, and the solution deposits it as the temperature falls.

Elain may be prepared by soaking in water the paper

employed in the preparation of stearin, or by mixing oil with *cold* solution of soda, which unites only with the stearin, so that, by filtration, the elain passes through along with the excess of alkali, from which it is easily poured off.

It is generally of a yellowish colour. Its sp. gr. varies from 913 to 930. Like the other, it is soluble in alcohol, and when mixed with warm alkaline solutions, forms soap.

Stearin and elain are contained in different quantities, in different substances. They have been found to be, in 100 parts of

	Stearin.	Elain.
beef marrow,	76	24
butter,	46	54
hogslard,	38	62
goose fat,	32	68
olive oil,	28	72
mutton marrow,	26	74
almond oil,	24	76

In prosecuting his enquiries into the nature of soap, formed by the action of alkaline matter on these principles, Chevreuil found that there exists in it no less than three acids, which he has called, *margaretic*, *oleic*, and *stearic*, the first so termed from its pearly appearance, (μαργαριτης, a pearl.)

Soap composed of alkali and hogslard is partly soluble. What is not dissolved, is precipitated in white flakes, composed of the alkali and *margaretic acid*, and which, by the addition of muriatic acid, is decomposed, the peculiar acid collecting on the surface in the form of pearly scales. These, when washed and dried, are destitute of taste and smell. At 134 they melt, and by a higher heat are decomposed. They redden vegetable blues, and unite with the bases, forming compounds, called *margarates*.

Oleic acid is procured by the addition of an acid to the solution of soap made of hogslard, by which it is separated in the form of an oily-looking fluid, but still mixed with margarate of potass, from which it is freed by the addition of an alkali, and afterwards of an acid.

It is an oily colourless fluid of sp. gr. 899; but which congeals at about 40. It reddens litmus, and unites also with the bases, and forms *oleates*.

Stearic acid is afforded also by the oils and fats employed in the manufacture of soap, but in different quantities. It unites with the alkalies, and forms *stearates*, much less soluble than the margarates and oleates; and hence, according to Chevreuil, the variety in soaps from the substance used in the manufacture.

Soaps of vegetable oils are composed chiefly of oleates and margarates, which vary in proportion in different oils; the more oleate, the softer the soap. Those of mutton suet, and hogslard, contain margarates, oleates, and stearates, the last of which communicate hardness; so that the more stearate, the harder the soap.

Chevreuil has found, also, that it is the stearin and elain that afford the acids existing in soap, the former yielding the margaretic and stearic, and the latter oleic acid, the decomposition and consequent formation of these being effected by the alkalies with which the oils are mixed; hence we are enabled to imitate different kinds of soap, by taking substances which contain stearin and elain to afford the requisite proportion of acids. Thus, by adding to oils that afford soft soap with soda, a substance that contains a large quantity of stearine, it becomes hard, the stearine affording by its action with the alkali stearic and margaric acids, which are yielded in small quantity by the other oil.

Ammonia unites with the oils, and forms a saponaceous compound, possessed of stimulant properties; and hence its use as a rubefacient. The *oleum ammoniatum* of the pharmacopœia[1] is prepared by shaking together one part of aqua ammoniæ and eight of olive oil.

The earths unite with the oils, and form soaps, differing from those containing alkali, in not being soluble in water. The only one of any interest is that with lime, having been long employed under the name of *carron oil*, as an excellent application to burns. It is the *linimentum aquæ calcis* of the Pharmacopœia, prepared by shaking together equal measures of oil and lime water.

Oil exerts little action on metals; hence the frequent practice of covering with it those liable to be affected by exposure to air. In some instances, however, it causes oxidation, as is particularly the case with copper, which, when besmeared with it, acquires a green crust.

The metallic oxids act on oil, the combination being effected either by synthesis, or by the addition of soap to a metallic salt. Those formed in the first way, are alone interesting, as affording the different kinds of *plasters*, and which are in general prepared by boiling the oil and oxid together. When plasters are long kept, they become very hard, but the proper consistence may be restored by the addition of a little more oil.

Most of the oils are soluble in alcohol; that most so, is castor oil, which unites with it in any quantity. They are in general more soluble in ether.

When oil is triturated in water along with sugar, gum, or starch, it is prevented from subsiding, probably owing to the viscid nature of the mixture.

The fixed oils are found in great abundance in a variety of plants, chiefly in the seeds and fruits; and the nearer they are to maturity, the greater is the quantity. They are obtained from them either by compression, or by boiling them in water, the oil in the latter case being easily separated from the water over which it floats.

Oil is employed for affording light. It is used also in the composition of paints and varnishes; but before being mixed with the paint, it undergoes a process, which makes it dry more easily. For this purpose it is boiled for some time, during which it becomes thicker, and of a darker colour. It is occasionally also set on fire, and allowed to burn for a short time; and after the flame is extinguished by putting on the lid of the pot, it is boiled till it becomes of the requisite consistence. It is sometimes also boiled with litharge, by which it undergoes a slight decomposition. By all of these processes, it loses its greasiness, and is thus rendered fit for the purposes of painters, and for the preparation of varnishes. For the former, it is mixed with white lead, and then with the paint; and for the latter, with oil of turpentine and resin.

Varnishes made in this way differ from those with spirit, in being much more flexible when dry, and of course not so liable to crack.

Oil is likewise used by printers. Nut oil is considered the best for black ink; and for other colours, that from lintseed is commonly employed. In preparing them, the oil is boiled as already mentioned, and then mixed with the requisite quantity of the colouring matter. During this process, it is evident that it must undergo some changes, for it adheres easily to moist paper, which it would not previously do.

Oil is employed also for yielding a gas, used as a means of affording light.

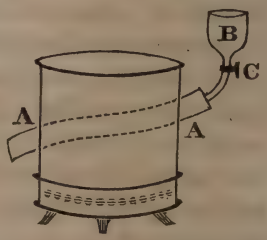
When oil is subjected to a red heat excluded from air, it is decomposed, its elements enter into a new state of combination, and a large quantity of gaseous matter, now called *oil gas*, is given off, which affords by its combustion a very brilliant light, and which as oil is composed chiefly of carbon and hydrogen, the proportion of oxigen being very small, contains little carbonic acid, and is entirely free from sulphur. For this reason it does not require to be purified; hence the method of preparing it is much more simple than that for procuring coal gas. For this purpose a reservoir full of oil is connected by a tube with a cast iron retort, placed in a furnace, and from the opposite end of which there pass tubes to the gasometer. Having stuffed the retort with pieces of brick or coke, it is made red hot, and the oil is then allowed to flow in, in a small stream, the use of the coke or brick apparently being merely to retard its progress, and thus expose it more completely to heat. The moment it enters the retort, it is decomposed, gas is formed, and passes into the gasometer. During its passage through the tubes, it deposits a little volatile oil and acetic acid, which are drawn off by a stopcock attached to them; but it still retains part of the former, which gives to it its peculiar odour.

The quantity of gas given off from oil varies according to the heat; 100 cubic feet may be got from a gallon,

but it seldom amounts to so much; in general 80 may be considered an average quantity. More may, however, be procured, but in this case it is of very inferior illuminating power. *(For the composition of oil gas, see Bitumens.)*

Different statements have been given of the comparative power of illumination of oil gas, and which has been occasioned in a great measure by the difference in its properties, owing to the method followed in procuring it, as it has been already mentioned, that the more there is obtained from a given quantity of oil, the illuminating power always becomes the less.

It has been found from numerous trials, that a foot of oil gas will afford a light equal to that of about from 6 to 8 tallow candles (short sixes), burning with a clear flame, supposing the quantity obtained from a gallon of oil to be about 80 feet. This makes the illuminating power to be about double that of coal gas, bulk for bulk. (Ed. Phil. Journ. xi. xii.)



The manufacture of oil gas on a small scale, may be shewn by a very simple apparatus. To one end of an iron tube A, passed through a chauffer, to bring it to a red heat, adapt a tinned iron funnel B, with a stop-cock C, having previously connected the opposite end to a gasholder. The funnel being filled with oil and the tube properly heated, the stopcock is to be opened and almost immediately shut, by which a little oil is allowed to flow in, and the moment it falls on the hot tube gas is given off, so that, by repeatedly turning the cock, a sufficient quantity may be formed to fill the gasholder.

Volatile Oils.

Volatile possess some of the properties of fixed oils, but they differ from them in many respects. Their characteristic feature is leaving a greasy stain on paper, but

which is easily removed by heat. Hence a method, not only of distinguishing them from other oils, but also of knowing whether they are pure. Thus, if a drop of common oil be thrown on paper, and held near a fire, part flies off, but before the whole can be dissipated, the paper is destroyed. If, on the contrary, a few drops of any volatile oil, as turpentine, be used, the stain disappears, without the texture of the paper being in the smallest degree injured. If, however, the latter be not pure, that is, if it be adulterated with any fixed oil, which is frequently the case, particularly with the more expensive ones, the spot does not entirely disappear; the volatile one flies off, but leaves the other. Owing to this property, volatile oils are sometimes employed for making paper transparent, with the view of copying drawings. The paper, being besmeared with pure volatile oil of turpentine, and dried by exposure to air for a short time, is put on the drawing, the traces of which are distinctly seen through it. After taking off the copy by a pencil, the oil is easily expelled by holding it near a fire.

The volatile oils are in general as fluid as water, though they are occasionally thick. Some are colourless, but others are of a bluish or greenish colour. They have a hot taste, and each has a smell peculiar to itself. They are generally lighter than water, but in a few instances they are heavier, as is the case with those of cinnamon and cloves. Oil of turpentine is of sp. gr. 792, of junipers only 611.

They are dissipated in vapour, at a temperature below that of boiling water, provided it is present, and they are not altogether excluded from the air, the vapour condensing unchanged in its properties. If the experiment be conducted in close vessels, they require a higher temperature for their volatilization, and they also undergo decomposition; they become black, and their odour is changed.

The congealing point of volatile oils varies; that of anise seed congeals at 50, of turpentine at 14, while

some require to be cooled to —17 before they become solid.

When exposed to light, they become thick and dark coloured, and are not so easily volatilized; hence the necessity of using recently prepared oil for rendering paper transparent. A similar change also occurs when they are long kept, particularly if not in well-stoppered phials, and which is owing to the absorption of oxigen. If long exposed to the air, they acquire so much consistence as to resemble a piece of resin.

When heated in contact with air, they take fire and burn with great rapidity, the products being carbonic acid and water; but if the combustion be not complete, as when they are burned on a plate, they give out a great deal of smoke. These experiments shew that the ingredients are the same as those of other vegetable matter. According to Ure, (Ph. Tr. 1822.) oil of turpentine is composed of,

carbon,	82.35 =	14 atoms
oxigen,	9.80 =	1 do
hydrogen,	7.85 =	10 do

When purified by distillation, it does not seem to contain any oxigen, an opinion supported by the experiments of Labillardiere, who maintains that 1 volume of its vapour is composed of 4 of olefiant gas, and 2 of carbon gas.

Volatile oils are soluble, though sparingly so, in water. By agitation, they communicate their flavour and odour to it; and hence the method of preparing waters impregnated with them, as those of peppermint and cinnamon.

They dissolve sulphur and phosphorus; but a few drops of volatile oil, with the exception of those of cinnamon and naphtha, when added to the solution of the latter in a fixed oil, destroy its luminousness.

They are acted on by chlorine gas with great rapidity, the action being, in general, accompanied with combustion, and the evolution of an immense quantity of smoke. The easiest method of showing the action, is to

soak a piece of paper in oil of turpentine, and, having suspended it from a plate of metal, put it into a bottle of the gas, standing on a plate of water, and instantly cover with a shade.

The acids act with great ease on volatile oils. When, for instance, nitrous acid is poured on them, the action is so violent as to cause the mixture to inflame. *(See Nitrous Acid.)* When the acid is diluted, the action goes on slowly, and oxalic and malic acids are formed. Sulphuric acid causes them to become black from the deposition of carbon. When muriatic acid gas is passed for some time through them, a whitish matter is deposited, resembling camphor in some of its properties, *(See Camphor.)*

Volatile oils do not exert a strong affinity for the alkalies and alkaline earths; they may, however, be made to unite with them by long continued trituration, and which is supposed to act by its enabling them to absorb oxigen, and become converted to a substance similar to resin, which it is well known unites easily with alkalies.

Volatile oils are soluble in alcohol, but the solubility varies in different cases. When water is added to the solution, the oil is deposited in minute globules, which, being suspended in the fluid, give it a milky appearance. They are also soluble in ether, and in the fixed oils.

Essential or volatile oils are found in almost all the different parts of plants; in each, however, they are contained in some particular part, though in a few instances they are dispersed through the whole. When in large quantity, they may be obtained by pressure, but they are usually procured by distillation. For this purpose the vegetable, cut into small pieces, is put into a still with water, and heat applied, by which the water and oil rise together in vapour, and are condensed in the receiver. As there is little attraction between them, they soon separate, so that the oil is easily got pure. Some of the volatile oils, as turpentine, are procured by distillation from resins.

Volatile oils are used chiefly in the preparation of varnishes and paints. They possess the valuable property of preventing vegetable matter from becoming mouldy; hence a few drops of oil of cloves are frequently mixed with ink. The effect of *Russia leather*, in preserving books, is well known. It operates in a similar manner in preventing mould, and which is owing to its containing a strong smelling volatile oil derived from birch-wood.

Camphor.

Camphor, which is nearly allied to volatile oils, is a white, soft, semi-transparent substance, having a crystalline appearance, a strong and fragrant odour, and a hot pungent taste. Its sp. gr. is 988.

It sublimes slowly even at a natural temperature, and the vapour condenses in slender crystals. It evaporates quickly at 150; at 288 it is fused, and at 400 it enters into ebullition. If the temperature be still farther raised, it takes fire, and burns with a bright flame, giving out much smoke, and the usual products, carbonic acid and water. When heated in oxigen gas, the combustion is very brilliant.

It has been analysed both by the destructive distillation *per se*, and with oxid of copper, by Thomson and Ure, the results being,

	Thomson.	Ure.
carbon,	73.91	78.02
oxigen,	11.6	10.40
hydrogen,	14.49	11.58

Camphor, if soluble in water, is so to a very small degree, the fluid acquiring the peculiar flavour when triturated with it.

Most of the acids dissolve it. When heated in nitric acid, it is dissolved, but at the same time altered in its properties, being converted to an acid called *camphoric*. The process for preparing it consists in boiling in a retort, to which a receiver is adapted, an ounce of camphor in four of acid, repeating the ebullition four or five times, with the same quantity, till the camphor ceases to rise in vapour, each time returning into the acid the matter that

sublimes into the receiver. During the process, nitric oxid and carbonic acid are disengaged, and a transparent fluid is left, which, when it cools, deposits crystals.

Camphoric acid is sparingly soluble in cold, but easily dissolved by boiling water. It is soluble also in alcohol, and the solution is not decomposed by admixture with water. It unites with bases, and forms *camphorates.*

When camphor is long digested in sulphuric acid, a substance is formed, possessing many of the properties of the astringent principle *tannin*, as was first shown by Hatchett, (Ph. Tr. 1805.) and afterwards confirmed by Chevreuil, *(See Tannin.)*

The action between alcohol and camphor is peculiar. When a few drops are poured on it, it is easily reduced to powder, which, before the addition of the spirit, could not be effected. When the alcohol is in larger quantity, it is dissolved, the solution being transparent and colourless, and easily decomposed by water, which precipitates it unchanged in its properties.

Camphor is soluble in the fixed and volatile oils, and in strong acetic acid.

Camphor is generally the produce of the *laurus camphora*, a native of Japan, from the wood of which it is obtained merely by sublimation, the product being afterwards mixed with lime, and again sublimed to free it from impurities. It is found, however, in many other vegetables, in the volatile oils of which it exists in considerable quantity, as in those of rosemary, sweet marjoram, sage, and lavender.

It has been already mentioned, that by the transmission of muriatic acid gas through oil of turpentine, a substance similar to camphor is gradually deposited. Though some are inclined to consider this as camphor, Gay Lussac asserts, that it is merely a compound of muriatic acid and the essential oil, neither of which has undergone any decomposition.

Camphor is used in medicine externally, dissolved in alcohol or oil as a rubefacient, and internally in diseases of the urinary organs, suspended in water in the form of emulsion, by means of sugar or almonds.

Resins.

Resins are solid brittle substances, generally of a yellowish colour, with some degree of transparency, and considerable lustre. When pure, they are destitute of taste and smell, but they have generally a peculiar odour and flavour, owing to impurities. They are heavier than water, their sp. gr. varying from 1020 to 1186.

When heated, they melt, forming a transparent fluid, which, as its temperature falls, again becomes solid without having suffered any change of composition. When the temperature is raised, they are inflamed, giving off the usual products, and a great deal of smoke.

Very different statements have been given of the component parts of resin, probably owing to a difference in the composition of the substances themselves, and to the presence of impurities, for it is well known, that they in general contain both water and an essential oil. The following is the result of the analyses :

	Thenard.	Ure.	Thomson.
carbon,	75.944	75.	63.15
oxigen,	13.337	12.5	25.26
hydrogen,	10.719	12.5	11.59

In one instance, in which the resin had been freed of impurities by long exposure to heat, the products were,

carbon,	49
oxigen,	49
hydrogen,	2

The discordance in these results shews, that the subject still requires farther elucidation, before we can conclude with certainty, with respect to the actual composition of resin.

Resins are insoluble in water, but when melted in it, they seem to unite, for they lose their transparency and brittleness.

The acids act on resin. By very cautious digestion in nitric acid, it is dissolved apparently without undergoing decomposition. If, however, the digestion be long continued, a solution is formed, which on evaporation yields

a substance resembling that called *extractive*, being equally soluble in alcohol and in water. If the action be still longer kept up, a matter is produced similar to tannin, or the astringent principle. *(See Tannin.)* Sulphuric acid slowly dissolves resin, even at a natural temperature, and from the solution it may be deposited unchanged in its properties. By the application of heat sulphurous acid gas is disengaged, the fluid becomes thick and dark coloured, and a substance remains undissolved, and from which alcohol takes up a matter similar in its properties to tannin, *(See Tannin.)* Acetic acid dissolves resin without decomposing it.

The alkalies dissolve resin, but when their carbonates are boiled on it, they enter into union, and form a saponaceous compound, from which acids precipitate it unchanged in its qualities. The use of resin in soap-making, has been already noticed. On the addition of a metallic salt to the solution, a precipitate of the oxid and resin is thrown down.

Resins are soluble in alcohol, in ether, and in the fixed and volatile oils, and from the solution they are precipitated by the affusion of water.

Camphor seems also to have an attraction for them, for when beat together the resin becomes soft.

Resins are obtained from juices which exude from different kinds of trees, either naturally, or through incisions in the bark. The fluid thus procured is a mixture of volatile oil and resin, which are separated by distillation, the former being driven off in vapour. They of course vary in their properties according to the tree from which they are procured. The most common are obtained from the varieties of fir, the juices of which are called turpentines. That of Scotch fir, when distilled, yields common resin; that of larch, Venice turpentine, and the balm of Gilead fir, Canada balsam. The fluid procured by the distillation of these is oil of turpentine, or what is commonly sold under the name of turpentine.

Other resins are obtained from different sources, as *copal*, from the *thus copallinum*, a native of America,

mastich, from the *pistacea lentiscus*, which grows in the Levant, and *lac*, said to be a deposit from insects, found on different species of trees, natives of the East Indies.

Resins, particularly copal, are employed as varnishes, and common yellow resin, when mixed with wax and oil, in the proportion of 4 wax, 2 resin, and 1 olive oil, forms a good luting for joining chemical apparatus, when heat is not to be applied.

Copal is white, with a slight tinge of brown. It is insoluble in water, and even in alcohol it is dissolved with difficulty, in this respect differing from common resins. It may, however, be dissolved in oils. When melted till it ceases to emit a peculiar odour, which it at first gives off, and then mixed with an equal quantity of lintseed oil, previously freed of its colour by exposure to the sun's rays, it is dissolved, and is in this state used as a varnish. Four parts of copal melted, and afterwards mixed with oil of lintseed, and about as much oil of turpentine as is equal to the whole mixture, form a varnish used by japanners.

Copal, it has been said, is acted on with difficulty by alcohol, and the volatile oils; we are obliged, therefore, to have recourse to a particular management to get it in solution. This may be effected by boiling it in them under an increased pressure, or by exposing it to their vapour, by which it is at first softened, and then dissolved.

Guaicum, the produce of a tree a native of the West Indies, is nearly allied in many of its properties to resins. It is soluble in alkalies and in alcohol, but in its action with acids, it differs from resins, in yielding oxalic acid, and little tannin. Its action with gluten has been already noticed. *(See Gluten.)*

Balsams are merely mixtures of volatile oil, resin, and the acid called *benzoic*. They are soluble in alcohol, ether, and some of the acids.

They are obtained from trees either by spontaneous exudation, or by incisions. The principal are *Balsam* of *Peru*, the produce of the *myroxolon peruiferum*, balsam of

Tolu, from the *toluifera balsamum*, *storax*, from the *styrax officinale*, and *benzoin*, from the *styrax benzoina*. They are chiefly used in medicine.

Gum resins are in their properties intermediate to resins and gum, and are not, therefore, to be considered distinct vegetable principles, being merely mixtures of those mentioned. They are not entirely soluble in alcohol, or in water, but proof spirit dissolves the greater part of them, the water taking up the gum, and the alcohol the resin. To this class belong *aloes*, *assa fœtida*, *myrrh*, *opium*, *gum ammoniac*, &c. They are used in medicine.

Caoutchouc.

Caoutchouc, or *Indian rubber* as it is frequently called, was brought to Europe from America, about the beginning of the last century, but at that time its history was not known. Condaminé, in 1755, ascertained that it was procured from the juice of a tree called Hevé, and it has since been obtained by Fresnou in Cayenne, and by others from trees which grow in India.

When pure, it is white, but it is generally of a brown or blackish colour, owing to the method of preparing it, the juice as it flows from the tree being collected on a mould, the form of which it is to take, and dried by exposure to the sun's rays, and then to smoke, successive layers being put on, till it is of the requisite thickness. It is destitute of taste and smell. Its sp. gr. varies from 930 to 1000. It is remarkable for its elasticity, a small slip being easily extended to a great length, and the moment the extending force is withdrawn, regaining its original dimensions. The elasticity varies with the temperature, becoming greater as this is raised. During the extension, a slight degree of heat is evolved, as is proved by drawing it out when placed between the lips. On the contrary, when it shrinks, there is a slight degree of cold.

Caoutchouc, when exposed to heat, softens and swells,

and emits an odour similar to that of burning hair. If the temperature is high, it burns with a bright flame. When heated in close vessels, it gives out the usual products. According to the analysis of Ure, it is composed of

carbon 90, hydrogen 9.12, oxigen 0.88;

and as the last is not in sufficient quantity to form an atom in proportion to the others, it is supposed adventitious.

Caoutchouc is insoluble in water. When kept for some time in it when boiling, it becomes soft and adhesive, which is however owing to the heat, and not to any particular action exerted on it by the fluid.

The acids exert very little action on it. It decomposes sulphuric and nitric acid, causing the evolution of sulphurous acid and nitric oxid; and in the latter instance oxalic acid is formed.

The alkalies act but feebly on it, even though aided by heat. By long digestion in their solutions, a little of it seems to be dissolved, and it loses its elasticity.

When boiled in alcohol, it becomes white, but is not dissolved or altered in its properties.

Ether very easily dissolves it, but it requires to be free from all foreign admixture; hence the cause of the discordant statements with respect to its action. Before attempting to dissolve the caoutchouc, it is necessary to wash the ether repeatedly with water, after which it acts as a ready solvent. The solution, by evaporation, affords it unchanged in its properties; and hence its use in making tubes and other articles.

Volatile oils also dissolve it by the aid of heat, but there is a slight decomposition; for on evaporation it yields a soft clammy substance. Perhaps the most active and cheapest solvent is the distilled oil of coal-tar, now known by the name of *naphtha*, in which it at first softens and swells to about 30 or 40 times its original bulk, and then disappears, forming a solution, the consistence of which depends on the quantity dissolved. This constitutes the patent process of Tennant of Glas-

gow, for getting it in solution, and which he uses in the manufacture of water-proof cloth, and other articles.

For this purpose, about 12 ounces of the caoutchouc, cut into small shreds, are put into a wine gallon of the oil, kept warm by means of a steam bath, the mixture being stirred till it becomes a thin pulp, after which it is passed through a very fine hair or muslin searce.

Caoutchouc, from its elasticity and power of resisting the action of chemical agents, is well adapted for many purposes; hence its use in making flexible tubes and varnishes. From the difficulty of getting it formerly in solution, tubes used to be made by cutting it into long pieces, softening by keeping them boiling in water, and then wrapping them round a piece of cane, and beating them till they adhered. This method is, however, now little followed, as the caoutchouc is so easily dissolved by coal tar oil, and which is so volatile, that when exposed to the air, it flies off, and leaves it, in its pure state, adhering to the substance on which it was spread. For making tubes, the solution is now applied to leather, or cloth, which is allowed to dry, and then wound round a cylinder, several coatings being afterwards given, by which the tube becomes quite air-tight. It is in the same way that the solution is now used as a varnish, the oil flying off, and leaving the caoutchouc. Hence also the method of making water-proof cloth, by soaking two separate pieces in the solution, and when they have become clammy by evaporation, passing them together between rollers, after which they are hung up in a warm room, till, by the dissipation of the oil, the caoutchouc causes them to adhere.

Caoutchouc exists in other plants than those mentioned. The *ficus Indica*, the *arctocarpus integrifolia*, and the *urceola elastica*, afford it. The *jatropa elastica* also yields it in considerable quantity.

Fourcroy found that the juice which had been sent home in well-stoppered phials, contained small pieces of caoutchouc in its inspissated state. When exposed to the air, the fluid part very quickly became solid, owing

to absorption of oxigen; and hence the difficulty of preserving it liquid.

Tan, Tannin, or Astringent Principle.

The substances called *nutgalls*, besides other ingredients, contain a matter which has been long known to afford a black precipitate, with a salt of iron, and to corrugate the animal fibre. These properties were first pointed out by Lewis, and afterwards by Deyeux and Seguin, and ascribed by them to the presence of a peculiar principle, which was first obtained in its separate state by Proust. It has been called *tan* or *tannin*, from its use in tanning. Its properties have been investigated by Davy and Hatchett, the latter of whom has pointed out a method of preparing it artificially.

Tannin, when pure, is a hard brown friable substance, having a peculiar smell, and a bitter astringent taste.

When heated in close vessels, it gives out carbonic acid, and an acidulous liquor containing an empyreumatic oil, and charcoal, in considerable quantity, is left in the apparatus. It contains, therefore, the usual ingredients of vegetable matter; and, according to Berzelius, in the proportion of

carbon,	50.55,	6 atoms,
oxigen,	45.	4 atoms,
hydrogen,	4.45,	3 atoms.

It is soluble in water, affording a brown solution, which, according to Tromsdorff, does not become mouldy, even though exposed to the air.

Tan is decomposed by the acids. When its solution is mixed with nitric acid, it becomes turbid, but very soon regains its transparency, and acquires a brown colour; the tan seems, however, to have undergone decomposition, for it does not produce the usual phenomena with other re-agents.

From the watery solution of tan, the diluted acids throw down precipitates, apparently compounds of the

acid and astringent principle. The fixed alkalies also yield precipitates from the solution, and which must be considered compounds of the tan and the substance added; but on the addition of excess of alkali, the precipitate disappears. That a union has taken place is evident, for re-agents added to the solution, produce phenomena altogether different from those occasioned by tan; but if the alkali be neutralized by an acid, the usual appearances are presented.

Many of the compound salts, as nitrate of potass, and muriate of soda, precipitate tan from its solution. When an alkaline carbonate is added, a powder is deposited, which is a compound of the salt and tan; but the fluid still retains a portion of the latter in union with the alkali; for if this be neutralized, the usual phenomena are produced by the re-agents that act on tannin.

Lime, baryta, and strontia, form precipitates of an olive colour, apparently throwing down the whole of the tan. The earthy carbonates also cause its deposition; but they differ from the carbonates of the alkalies, in not forming soluble compounds with it.

Many of the metallic oxids also unite with tan, and form substances called *tannurets*. The compounds may be formed by boiling the solution on the oxid, or by mixing it with that of the metallic salt. By far the most important action is with salts of iron. When infusion of tan is added to its proto-sulphate, there is little or no change, but with the per-sulphate it throws down a black precipitate. Of course, on exposing to air the mixture of tan and the proto-salt, the dark colour gradually appears. This compound is supposed to contain protoxid of iron, the excess of oxigen in it having passed to the tan. It is decomposed by the acids, which, uniting with the iron, set the tan at liberty. Thus, on adding sulphuric acid to the black fluid, it instantly becomes colourless, but the colour may be recalled by the neutralization of the acid by any alkali.

Salts of lead, of tin, gold, platinum, and antimony, also precipitate tan from its solution.

Alcohol, which is freed as much as possible from water, does not dissolve tan; but if it contain a minute quantity of it, so as to make it of sp. gr. 818, it forms with it a solution of a brownish colour.

Tannin is contained in a great many vegetables, from which it is not spontaneously afforded pure, like most of the other principles, being in general mixed with mucilage, an acid called gallic, and extractive matter.

The substance that yields it in greatest quantity, is nutgalls, excrescences on the leaves of the oak, occasioned by the puncture of a small insect. They are of a round form, and have a disagreeable bitter taste. According to Davy, 500 grains of Aleppo galls afforded, by evaporation of their solution, 185 grains, 130 of which were tan, the remainder being mucilage, gallic acid, and extract. It is contained, also, in the leaves and bark of a great many vegetables. The bark of the oak, of the Leicester willow, and Spanish chesnut, souchong and green tea, shumac, the shoots of the rhus coriara, dried and ground to powder, contain it in considerable quantity. Davy has found that the inner bark has more than the outer; accordingly, young trees which have the former in excess, yield more than old ones.

Catechu, or *terra japonica*, extracted by decoction from the wood of the *acacia catechu*, contains a very large quantity of it; 480 grains of Bombay catechu afforded 261, while that from Bengal yielded 231.

Kino, an extract from the *cocoloba uvifera*, or sea-side grape, growing in Jamaica, and also from the different species of *eucalyptus*, particularly the resinifera, or Botany Bay gum-tree, consists chiefly of tannin.

Tannin, it has been mentioned, exists in the different substances that yield it, along with mucilage, extract, and gallic acid, with which it is so intimately blended, that though several processes have been recommended for separating them, it is doubtful if any yields it pure. That given by Tromsdorff is, according to Thomson, by far the best. Three parts of galls, in powder, are digested in 40 of water for three days, and after pouring

off the solution, the digestion is repeated several times, to extract the whole of the soluble matter. The fluid thus obtained is evaporated to about a fourth, then strained and evaporated to dryness, and the residue digested repeatedly in pure alcohol, about 1-10th of water being mixed with the last portion, to ensure the removal of the whole of the gallic acid. The residue is then dissolved in water, and, by exposure to air, the mucilage which it contains, is separated by becoming mouldy; and by the addition of carbonate of potass, the sulphate of lime, also present, is removed. After filtration, acetate of lead is next added, to precipitate the tannin, and by passing sulphuretted hydrogen through water, holding the tannuret in suspension, the metal is removed, and the tan left in solution.

Tan, or rather the substances in which it exists, are employed abundantly in the arts. From its power of striking a black colour with salts of iron, it is used in dyeing, *(See Colouring Matter,)* and in the manufacture of ink.

In the preparation of ink, the only substances necessary for producing the colour, are astringent matter and a salt of iron, but others are added to impart particular qualities. Thus, gum arabic makes it more consistent, keeping the black matter suspended, and also preventing the ink from spreading on the paper; and sugar, or sugar candy, gives it a gloss. Logwood, it is said, renders the colour darker, a property also possessed by the salts of copper; and by some, vinegar is employed, either alone or mixed with water. The use of these two last ingredients is, however, attended with considerable inconvenience, the former acting on the knife with which the pen is cut, provided it is not quite clean, and thus destroying its edge, while the latter softens the quill, and causes it to require to have the nib frequently renewed.

The different receipts for making ink very nearly agree with each other; they differ only in the proportions of the ingredients. Perhaps the simplest is the following. Put into a bottle three ounces of nutgalls

bruised, two ounces of logwood bruised, one ounce of green vitriol, an ounce of gum arabic, and a quart of water. The bottle ought to be kept loosely corked for about a fortnight, and frequently shaken, after which the cork must be tightened.—A much better ink is prepared by the following. In six quarts beer measure of water, boil four ounces of campeachy logwood for about an hour, adding occasionally a little water to compensate for loss by evaporation; strain while hot, and when cold make up the quantity to 5 quarts, then add 20 oz. nutgalls bruised, green vitriol dried in an iron ladle over a fire to whiteness, 4 oz.; coarse brown sugar, 3 oz.; gum-arabic 6 oz. (or for less glossy ink half the quantity). The whole must be well mixed and shaken twice a day during fourteen days, keeping the vessel loosely corked, to admit the air to act on the iron, and make the ink darker. After this the impurities are allowed to subside, and the fluid poured off.

Ink is apt to become mouldy, to prevent which, some cloves, or a few drops of any essential oil, as that of peppermint, may be added. Its greatest imperfections, however, are its fading when writings have been long kept, and being destroyed by acids; the former owing to the decay of the vegetable principle, the latter to the decomposition of the black tannuret, by the acid. As, in the first instance, the iron still remains on the paper, the traces may be recalled by sponging it with solution of nutgalls; and in the last, provided the texture is not destroyed, all that is necessary is to neutralize the acid, for which purpose an alkaline carbonate, as that of ammonia, is employed.

Another method of recalling the characters, is by sponging the paper with a weak solution of ferro-cyanate of potass, and afterwards with very much diluted muriatic acid, by which they acquire a fine blue colour.

Chlorine also destroys ink. If the traces have been banished by it, they may be recalled, by rubbing the paper with a weak solution of hydro-sulphuret of potass.

Another very important practical application of the

astringent principle, is in *tanning*, or the converting of gelatinous animal matter to leather. *(See Gelatin.)*

Artificial Tan. We are indebted to Mr Hatchett for the valuable discovery of the method of preparing tan artificially. When investigating the properties of resins, he discovered, that, by the action of nitric acid, they afforded a substance similar to tan. He afterwards found, that the same was produced by other vegetable bodies, as by coal, some of the balsams, and gum resins; and, indeed, from all those containing much carbon, which induced him to try the effect of nitric acid on charcoal itself; and from it he also succeeded in obtaining it. Various methods have been pointed out by him for preparing artificial tan, (Ph. Tr. 1805-6,) but that with charcoal is the easiest. 100 grains of charcoal are digested in an ounce of nitric acid, of specific gravity 1400, diluted with two of water, till the whole is dissolved, adding acid when the action ceases. On evaporation of the solution, tannin is obtained; and, to free it from any adhering acid, it is again dissolved, and cautiously evaporated. By this process, 100 grains of charcoal yield about 120, of which 3 seem to be water.

Artificial tan is, in most of its properties, the same as that obtained from astringent plants, being soluble in water, and precipitating the metallic salts very nearly of the same colour. In its action with nitric acid, however, it is different, for natural tan is decomposed by it; whereas the artificial is not only produced by its agency, but is soluble in it, without decomposition.

There is still another method of preparing artificial tan pointed out by Hatchett. It consists in the application of heat to a mixture of sulphuric acid and resin, or camphor, till it becomes black. By the addition of water to the solution, a powder is precipitated; which, when treated with nitric acid, affords tan. It is probable that this process, and, indeed, that the whole of those mentioned by Hatchett, are the same as that already described; for it is well known, that by the addition of water to solutions of vegetable matter in sulphuric acid,

carbon, in a fine state of division, is precipitated, so that the astringent principle is, in reality, formed by its action with nitric acid.

Extract, or Extractive.

By the *extract* of vegetables, is meant that part soluble in water, the solution, on evaporation, affording a substance of different colours, according to the plant from which it is obtained. It is evident that the matter procured in this way, must contain a variety of ingredients, as gum, sugar, tannin, &c., so that it must vary in its properties. Some are, however, inclined to think that there is a principle possessed of peculiar qualities, to which they give the name of *extract* or *extractive*.

It may be procured by boiling the sap of some trees, during which it is coagulated, and falls to the bottom of the vessel. Saffron, catechu, gentian, senna leaves, Peruvian bark, and many other medicinal plants, also yield it by decoction.

Extractive is soluble in water, affording a solution, which, when exposed to air or to heat, yields a precipitate not again soluble in the same menstruum. It is decomposed also by chlorine, and by the acids and alkalies, all of which throw down dark coloured precipitates. When boiled with a salt of alumina, a precipitate appears, and the solution becomes nearly colourless. The same likewise occurs with the oxids of some metals, and with their salts. When, for instance, muriate of tin is added to it, a brown-coloured precipitate is formed.

Extractive is soluble in alcohol, and the solution is not decomposed by water.

From what has now been said of the properties of extract, we are enabled to judge whether it really deserves to be considered a distinct vegetable principle. Its solubility in water and in alcohol, and the change effected on it by boiling, or by exposure to air, would at first sight induce us to believe, that the infusions of the vegetables mentioned, do really contain a matter different from those

already described; but if we examine them more minutely, an opposite opinion may perhaps with more propriety be entertained. The solutions supposed to contain extract, must have in them a variety of substances, which together, on the addition of re-agents, may present phenomena not to be obtained by any one principle; and hence probably the cause of the difference of the extracts from different bodies. Some are more soluble in water than in alcohol, others the reverse; the former may, therefore, contain more mucilaginous, the latter more resinous matter. Chlorine, the alkalies, and metallic salts, produce precipitates from extracts, but the same happens with tannin. The appearance of resin in the watery solution, may be accounted for by the presence of acetic acid, which has also been detected in them. From these different circumstances we may infer, that what is called extract, is merely a combination of the parts of plants soluble in water, as gum, tannin, and some others, and along with these a few of the principles not soluble in it, but rendered so by the presence of the former or others, and that the chemical qualities ascribed to it are the result of re-agents on them, either separately or in combination. At all events, till more decisive proofs are brought forward, the existence of a distinct principle, possessed of properties ascribed to extract, may with justice be called in question.

Bitumens.

By bitumens are meant those compound inflammable bodies, which, though of vegetable origin, are found in the earth, or on its surface. They may be divided into two classes, the liquid, and solid. To the former belong, naphtha, petroleum, and mineral tar; to the latter, asphaltum, mineral caoutchouc, retinasphaltum, and coal.

Naphtha is a pale yellowish-coloured volatile oil, found on the shores of the Caspian Sea, and in Persia. It has a pungent disagreeable smell. Its sp. gr. when purified by distillation, is 758.

When heated in close vessels, it may be distilled, and condensed unchanged in its properties, but when air is

present it burns with a white flame, giving out much smoke. When its vapour is mixed with oxigen, it burns with a flame similar to that of olefiant gas, and in this way, and by heating it with oxid of copper, the proportions of its ingredients have been ascertained; but very different statements have been given of its composition. According to Thomson, its component parts are,

carbon, - - - - -	82.2
hydrogen, - - - - -	14.8
deficiency, supposed to be azote,	3

Naphtha, therefore, differs from the vegetable substances formerly described, in not containing any oxigen, and hence its use in preserving the metallid bases of the alkalies, *(See Potassium.)*

By long exposure to air, naphtha becomes thick, and similar to petroleum. It is not dissolved by water or by alcohol. It dissolves sulphur and phosphorus by the application of heat, and deposits them in their crystalline form as it cools. It unites with ether, and with the fixed and volatile oils. It dissolves caoutchouc, but the solution on evaporation leaves it of a clammy consistence.

Naphtha similar in its properties to that described, is now obtained by the distillation of coal tar. It is transparent and colourless, extremely volatile and inflammable. It dissolves caoutchouc, and hence its use in forming air-tight tubes, and waterproof cloth, (*See p.* 197.)

According to Thomson, its vapour is composed of 6 volumes of carbon gas, and 6 of hydrogen condensed into 1 volume.

Petroleum is a fluid of a thicker consistence than naphtha, and of a darker colour. When subjected to distillation, it yields a colourless naphtha, along with an acidulous empyreumatic liquid, leaving a dark tarry-looking matter in the retort. When exposed to the air it becomes thicker, and it is thickened also by acids. When heated in air it burns, giving out much smoke.

Mineral tar is thicker than petroleum, but similar to it in all its properties.

Asphaltum is found in great abundance on the shores of the Dead Sea, and in Trinidad. It is dark brown

approaching to black. Its sp. gr. varies from 1070 to 1165. When heated in a retort, it yields olefiant gas, and an empyreumatic fluid, containing ammonia, and leaving a black carbonaceous residuum. It is insoluble in water, in acids, alkalies, and alcohol. It is soluble, however, in ether and the volatile oils, but its most ready solvent is naphtha, which dissolves about 1-5th of its weight of it, and forms a dark brown solution, from which the volatile matter flies off, by exposure to air, and hence its use as a varnish.

Mineral caoutchouc, and *retinasphaltum*, the former found in Derbyshire, and the latter in Devonshire, are nearly of the same quality. They are of a dark brown colour, inflammable, and by distillation at a red heat, yield carburetted hydrogen, and an empyreumatic oily fluid, leaving a dark carbonaceous residue.

Pit coal, by far the most abundant and useful of the bitumens, is generally divided into three species, brown coal, black coal, and glance coal.

Brown coal is flexible and elastic, containing a considerable quantity of volatile mater, easily procured from it by distillation. It has a fibrous texture, bearing evident marks of its origin. It burns with a bright flame, yielding a peculiar bituminous odour. It is found in Bovey in Devonshire, in Iceland, and in several parts of Germany.

Glance coal or *anthracite*, consists almost entirely of charcoal, with a very small proportion of earthy impurities. It burns with little flame, and when subjected to heat in retorts, yields a minute quantity of carburetted hydrogen, but little or no tar. It occurs in Kilkenny, and in several parts of this kingdom.

Black coal is by far the most interesting of the varieties, not only from its abundance, but its use as fuel. It has been divided by Dr Thomson into four sub-species, (An. of Ph. xiv.) caking, splint, cherry, and cannel coal.

Caking coal is so called, because, by the application of heat, part of it is melted, and causes the whole to run

into one mass. Newcastle coal, and that found in different parts of England, are of this kind. It is soft, and easily broken. It is easily kindled, and burns with a lively flame, giving out more heat than any of the other kinds; but owing to its caking, it requires to be frequently stirred, to admit the atmospherical air.

Splint coal, so called from its splintery appearance, though not harder than the preceding, is broken with more difficulty, and requires a higher temperature to kindle it. It is much employed for yielding *coke*, and in the reduction of metallic ores, particularly iron.

Cherry coal is of about the same degree of hardness as caking coal, and is also easily broken. It is easily kindled, and burns with a bright flame, giving out much heat. It does not cake, but, on the contrary, is quickly consumed; hence it is not so economical as the others. It occurs in great abundance near Glasgow and in Fifeshire. In some parts of England it is employed for smelting iron.

Cannel coal is distinguished from the others, by its hardness, and its capability of receiving a fine polish; and hence it is frequently cut into ornaments. It is much more easily kindled than any of the preceding, and during its combustion gives out a bright flame, but little heat; it splits also with a crackling noise, and hence the name of *parrot* coal. It occurs in different parts of Scotland, in Wigan in Lancashire, and in other places in England.

Dr Thomson has given the following as the result of his analysis of these different kinds of coal.

	Coking.	Splint.	Cherry.	Cannel.
carbon,	75.28	75.0	74.45	64.72
oxigen,	4.58	12.5	2.93	0.
hydrogen,	4.18	6.25	12.4	21.56
nitrogen,	15.96	6.25	10.22	13.72
	100.00	100.00	100.00	100.00

The ingredients in the above table are independent of the incombustible matter, which Dr Thomson found to

vary, in the different instances, from 1.5 to 11 per cent. 100 parts of caking coal affording 1.5, of splint 9.5, of cherry 10, and of cannel 11 of ashes.

The quantity of coke, and matter volatilized by heat, also varied, as is shewn in the following table;

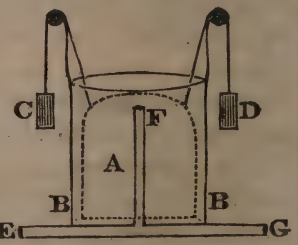
	Caking.	Splint.	Cherry.	Cannel.
Coke,	774	647.3	522.5	400
Vol. mat.	226	352.7	477.5	600
	1000	1000.0	1000.0	1000

Though the above species of black coal vary in their composition, yet in their general properties they are similar. They all afford carbonic acid, water, and ammonia, during their combustion; and when heated in close vessels, they give off different compounds of carbon and hydrogen, carbonic acid, carbonic oxid, water, and ammonia; but besides these, sulphuretted hydrogen and tar are generated. As the heavy hydro-carbons are in considerable quantity, the gaseous matter generated by the destructive distillation of coal, now called *coal gas*, is employed for artificial illumination.

For generating the gas, the coal, reduced to small pieces, is thrown into long iron cylinders, previously heated, and on the open end of which a lid is placed, as quickly as possible after the introduction of the coal, and secured by a screw and luting. Decomposition instantly commences, and the gaseous matter generated is conveyed from the opposite end of the retorts, through tubes, to its place of destination. In this part of the process, it is of the utmost consequence to pay particular attention to the heat. When coal is put into a *cold* cylinder, and gradually warmed, or when introduced into one previously brought to a *white heat*, the gas given off has but a faint illuminating power. When, however, it is thrown into the retort brought to a *bright cherry* heat, it instantly yields a large quantity of good gas. As the heavy hydro-carbons are easily decomposed by passing over ignited surfaces, it is of consequence also to remove the gaseous products as quickly as possible from

the retort, lest they should be deprived of part of their carbonaceous principle, and which is the chief source of the light.

The gas, issuing from the retort, is conveyed by tubes to a vessel of water, through which it passes, and where it deposits tar and a strong-smelling volatile oil. It is next carried to the condenser, a large iron vessel, divided into different compartments by perpendicular partitions, and in its passage along which, more of the tarry matter, and an ammoniacal salt, are deposited, occasioned by mere reduction of temperature, for the partitions being hollow, are kept always full of cold water. From this it proceeds to the purifier, a vessel containing *milk of lime*, the use of which is to remove the sulphuretted hydrogen and carbonic acid; and after passing through this for a sufficient length of time, it is conveyed to the gas-holder. This is a large vessel made of sheet iron A, open below but shut above, and suspended in a tank of water B B, by means of chains which pass round pulleys, and have weights C D, fixed to the opposite end. E is the induction pipe passing to the top of the tank F. G is the exit pipe. When the coal is put into the retorts, the gas-holder is sunk in the water, and as the gas flows in, it gradually raises it, the weights preventing it from exerting much pressure on the gas. As, however, the gasometer is not completely counterpoised, the moment the stopcock of any tube coming from it is opened, the gas is forced out by the gasometer falling in the tank. Of course the pressure to be given depends entirely on the distance to which it is to be conveyed, and the number and size of the tubes through which it has to pass.



The nature and properties of coal gas, vary according to the coal from which it is procured, and the mode of preparing it. From the numerous experiments of practical men, it has been found that 2 cwt. of coal should

yield about 1000 feet of gas, the sp. gr. of which varies from 450 to 700. It seldom, however, exceeds 600. The following is the composition of different specimens given by Dr Henry, (An. of Ph. xviii.)

Gas.	Sp. Gr.	Gas conducible by chlorine.
No. 1.	650	13
2.	620	12
3.	630	12
4.	500	7

After the condensible gas was removed, there remained,

	Azote.	Carb. Hyd.	Carb. Ox.	Hyd.
1.	1.5	94.5	4	0
2.	6	82	2	10
3.	2	66	14	18
4.	5	60	12	23

The gas condensible by chlorine is olefiant, and the other kinds of heavy hydro-carbons; for it has been lately shewn by Faraday, that in oil gas, and probably also in that from coal, there exist other compounds of carbon and hydrogen, than olefiant and common carburetted hydrogen.

When coal gas, properly purified, is heated in contact with air, it burns with a bright white flame, mixed with blue near the burner; the products of the combustion being carbonic acid and water.

Different statements have been given of its illuminating power. Of course it must vary according to its mode of manufacture, and the coal from which it is procured, and a great deal must also depend on the mode of burning it. Three methods have been recommended for ascertaining this. 1*st*, Producing from similar burners the same *intensity of shadow*, and marking the quantity consumed. 2*d*, By ascertaining the *quantity of oxigen* necessary for the complete combustion of a certain proportion of gas. 3*d*, By finding the amount of gaseous matter, *absorbable by chlorine* in the dark. The last I have found not only the simplest, but apparently the most free from objection, because it points out the actual quantity of the heavy hydro-carbons, and which are the true source

of light, (Ed. Ph. Journ. xi.) By these different methods, it has been shewn, in the paper alluded to, that an argand burner, No. 2. of Edinburgh, and which consumes rather more than 3 cubic feet of gas per hour, when burning with a proper flame, about 3 inches, gives in general a light equal to that of about twelve tallow candles, (short sixes,) burning with a clear flame.

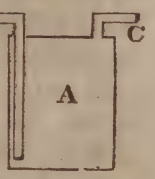
With respect to the comparative illuminating power, and of course comparative economy of coal and oil gas, it has been already mentioned, (p. 186.) that the light given by the latter, per cubic foot, is equal to that of about from 6 to 8 candles, making it nearly double that of the former, and this is confirmed by the chlorine test; the absorbable gaseous matter, per cent. in good coal gas, varying from 14 to 18, that in good oil gas from 25 to 32, or nearly so, because the quantity varies considerably according to the mode of manufacture. Considering oil gas as giving only twice the light of coal gas, bulk for bulk, and as its price is in general more than three times that of the other, it must, for the purpose of illumination, be considered nearly twice as expensive, and without possessing any advantages over it; for the latter, when properly purified, does not contain any noxious ingredient *.

It has been already mentioned, that in certain parts of the apparatus, tar and an essential oil are deposited. These are sold to refiners, who separate them by distillation. The latter is distilled over, and condensed in receivers, and is now much used for dissolving caoutchouc; the former, which is left in the still, is used for covering the roofs of houses and wood work. (*See Caoutchouc* and *Tar.*) In some manufactories, the tar is consumed as a means of heating the retorts where the gas is generated, by which much of the nuisance occasioned by conveying it from one place to another is avoided. Besides these, there is also a large quantity of ammoniacal fluid,

* These remarks apply to gas procured from Scotch coal, the illuminating power of which is far beyond that of the gas from English coal. *See* papers in the Edinburgh Philosophical Journal, xi. xii.

produced during the decomposition of the coal, and which is sold to manufacturers of sal ammoniac. *(See Sal Ammoniac.)* After the whole of the gas is driven off, there remains in the retorts a black inflammable matter; it is coke, and is either used for heating the retorts, or sold to confectioners and others, in whose processes coal would prove injurious from the smoke it gives out.

The manufacture of coal gas, on a small scale, and sufficiently pure to shew its illuminating power, may be conducted by putting pieces of coal into an iron retort, the mouth of which is connected to a purifying apparatus, A, made of tinned iron, filled with milk of lime. B is the induction pipe, to which the mouth of the retort is adapted, and passing down to the bottom, so that the gas may be made to flow through the fluid. C is the exit-pipe, connected with the gasometer, which ought also to be filled with milk of lime. On placing the retort into a furnace, or common fire, when properly heated, the gas escapes, and passing through the lime, deposits the greater part of its impurities, after which it flows into the gas-holder, and from it may be forced out in the usual way, and burned, by adapting a gas-burner to its exit-pipe.



A familiar method of shewing the production of inflammable gas from coal, is to fill a tobacco pipe with it, cover it with putty, and place it in a fire. In the course of a few minutes a dense white smoke appears at the mouth of the pipe, and which, on applying a flame, is kindled, and continues to burn for some time.

It has been already mentioned, that the gaseous matter given off during the decomposition of coal and oil, by heat, consists chiefly of carburetted hydrogen and olefiant gas; but besides these, other compounds of carbon and hydrogen are also generated, some of which remain in the gaseous fluid after purification, adding greatly to the illuminating power, while others are carried along with the impurities. The volatile oil of naphtha, procur-

ed by the distillation of tar, must be considered as one of these. Its composition, as already mentioned, (p. 206.) is, according to Thomson,

6 volumes of carbon, } condensed into 1 volume.
6 do hydrogen, }

During the rectification of coal tar, by which the volatile naphtha is procured, a crystalline-looking matter is deposited in the receiver, more particularly from the last portions that come over, and to which the name of *naphthaline* has been given by Mr Kidd, (Ph. Tr. 1821.) By pressing it between bibulous paper, and dissolving it in alcohol or oil of turpentine, it may be obtained in its crystallized state by evaporation.

It has a smooth unctuous feel, and a strong pungent odour. Its sp. gr. is 781. It melts at 180, and boils at 410. When heated in air, it burns, affording carbonic acid and water. It is insoluble in water, but easily dissolved by alcohol, ether, and volatile oils. According to Ure, its composition is,

carbon,	92.9	or	2 atoms
hydrogen,	7.1		1 do.

but Dr Thomson, from his analysis, (F. Pr.) makes it a compound of 2 atoms hydrogen, and 3 of carbon.

During the compression of oil gas into the portable lamps, and by which it is exposed to a pressure of about 30 atmospheres, a volatile fluid is deposited in considerable quantity, and which has been examined by Mr Faraday. By the application of heat, it is converted into vapour, but the boiling point varies considerably during the evaporation; and which led him to suppose that it might contain different compounds. By keeping up the ebullition at a temperature between 170 and 190, and subjecting the condensed vapour to zero, he procured a hard solid substance, to which he gave the name of *bicarburet of hydrogen.*

At a natural temperature, it is a transparent colourless fluid, having the odour of oil gas, and of sp. gr. 850 When cooled to 32, it becomes solid and crystallizes, and at 186 it boils with rapidity. When heated in air, it

burns with a bright flame, but giving out a great deal of smoke. When passed through incandescent tubes, it deposits carbon, and emits carburetted hydrogen. It is not soluble in water, but alcohol, ether, and oils dissolve it.

Mr Faraday succeeded in ascertaining the proportions of the ingredients of this compound, by decomposing it by peroxid of copper, and by exploding its vapour with oxigen: 100 volumes he found required 750 of oxigen for complete combustion, and 600 of carbonic acid and water were the results; now as 600 of carbonic acid contain 600 of carbon vapour, and 600 of oxigen, the remaining 150 of oxigen must have united with 300 of hydrogen, to generate the water; so that the composition must be

carbon 6 volumes,
hydrogen 3 do. } condensed into 1.

And as a volume of each represents an atom, it contains

carbon 6 atoms or 92.34
hydrogen, 3 atoms or 7.66

When the liquid from the compressed gas is heated to about 90, a vapour arises from it, which, when passed through tubes cooled to zero, is condensed in the form of a colourless fluid. This, according to Faraday, is another compound of carbon and hydrogen. At zero its sp. gr. is only 627. When its temperature is allowed to rise, it begins to evaporate, and before it has reached 32 it is all converted to vapour, which is absorbed sparingly by water, but in large quantity by alcohol: 100 volumes require for combustion 600 of oxigen, and form 400 of carbonic acid; it must consist therefore of,

carbon 4 volumes,
hydrogen 4 do. } condensed into 1,

or 4 atoms of the former and 4 atoms of the latter.

Mr Dalton has described another compound of carbon and hydrogen, under the name of *super-olefiant gas*, and which he conceives exists in coal and oil gas. According to Henry, 100 volumes require 450 for combustion, yielding 300 of carbonic acid; so that it must consist of,

carbon 3 volumes,
hydrogen 3 do. } condensed into 1.

that is, of 3 atoms to 3 atoms.

From what has now been said with respect to the compounds of hydrogen and carbon, it is evident that, even leaving out naphtha, the composition of which has not been yet satisfactorily determined, there are no less than 6 varieties of hydro-carbons, the proportions of the ingredients of which are,

			Hyd.	Carb.
carburetted hydrogen,	vol. 1.	contains	2	1
olefiant gas,	—	—	2	2
super-olefiant gas,	—	—	3	3
Faraday's 2d fluid,	—	—	3	6
Faraday's bicarburet,	—	—	4	4
naphtha from coal,	—	—	6	6

On inspecting the above table, even the most superficial observer must be at once struck with the remarkable fact, that there are no less than four compounds, containing exactly the same proportions of carbon and hydrogen; and as there is no reason to doubt the accuracy of the analytic experiments performed, if not on the whole, at least on some of them, the only way to account for the diversity in their properties, is to suppose either that the elements must themselves be in a certain state of union before they enter into combination with each other, or that the integrant atom of each compound is made up of a different number of the elementary ones, though always bearing the same ratio to one another.

Lignin.

The name of *lignin* has been given to that principle left after removing all the soluble matter from wood or other vegetable bodies, by the action of water, alcohol, and weak muriatic acid, and which seems to be the same in its properties, from whatever substance it is procured.

It is destitute of taste, smell, and colour. It is not liable to be affected by exposure to air, except when moist, in which state it becomes mouldy, the oxigen of the air being consumed, and its place supplied by carbonic acid.

When exposed to heat in close vessels, it yields a transparent colourless fluid, of sp. gr. 828, having a strong pungent odour, similar to that of ether. It boils at 150; and when heated in air, burns with a blue flame, without leaving any residue. It is not soluble in water or in volatile oils, but in alcohol. Macaire and Marcet, to whom we are indebted for the account of the properties of this fluid, and which they call *pyroxilic spirit*, found it to contain nearly 6 atoms carbon, 4 of oxigen, and 7 of hydrogen, (An. of Ph. N. S. viii.)

Lignin, or rather wood, yields also, by distillation, pyroligneous acid, which, it has been already noticed, (p. 158.) is merely acetic disguised by empyreumatic oil.

Lignin is acted on by acids. With nitric it yields oxalic and citric acid. Sulphuric acid chars it, and causes the deposition of charcoal. The conversion of vegetable matter, by sulphuric acid, into gum and sugar, as the sawings of hornbeam, and probably from the presence of lignin, has been mentioned, (p. 168.)

Gay Lussac and Thenard have analysed lignin, and found it composed of

carbon,	52.53	or 7 atoms
oxigen,	41.78	- 4 atoms
hydrogen,	5.69	- 4 atoms;

so that the oxigen and hydrogen are in proportion to form water.

When lignin is digested with potassa, it is softened, and a solution is obtained, from which acids precipitate a matter similar to ulmin, (An. of Ph. xvi.)

The principles, the properties of which have now been described, are dispersed throughout the vegetable kingdom, and have been long known as peculiar bodies. Of late, however, a great variety of substances has been added to the list, many of which are confined to a few, or even to one particular plant; and the properties of some of these have been but very little investigated; indeed, so little is known of them, that it is doubtful whether they

ought to be admitted as distinct principles. Others, however, though not minutely examined, seem well defined objects.

Suberin.

When cork, the bark of the *quercus suber*, is treated with successive portions of water and alcohol, a substance is left, to which Chevreuil has given the name of *suber* or *suberin*. It differs from lignin, and the other principles already noticed, in not yielding oxalic or malic with nitric acid, the product being a peculiar one called *suberic*, and which unites with bases, and forms *suberates*, (An. of Ph. ix.)

Fungin.

Mushrooms have, by Braconnot, been found to contain a peculiar principle, to which he has given the name of *fungin*. It is obtained by washing the fleshy part with a very weak warm alkaline solution, after which there remains a white, insipid, soft substance, easily decomposed by heat, and yielding ammonia, shewing that it contains nitrogen. It is decomposed also by nitric acid, with the disengagement of nitrogen. Alkaline solutions do not dissolve it, except when strong, and the action is aided by heat. These properties shew that fungin is not only different from lignin, but that it bears a strong resemblance to the principles of the animal kingdom, (An. de Chem. lxxix.)

Cathartin.

Senna leaves have been found, by Lassaigne and Fenuelle, (An. de Ch. et de Ph. xvi.) to yield a peculiar principle, to which they give the name of *Cathartin*. By the addition of sub-acetate of lead to the infusion, a precipitate is formed, which, when acted on by sulphuretted hydrogen, is freed of its lead, while cathartin is left in solution. To purify it, it is evaporated to dryness, dissolved in al-

cohol, and again evaporated. On the addition of alcohol, acidulated with sulphuric acid, potassa existing in the solution is deposited in the state of sulphate; and, by adding acetate of lead to precipitate excess of sulphuric acid, and sulphured hydrogen to throw down the lead, the cathartin is left in solution, and is obtained pure by evaporation. It has a reddish brown colour, and a bitter nauseous taste; is soluble in water and alcohol, but not in ether. When administered in very small doses, it acts as a powerful purgative.

Narcotin.

The stimulating effects of opium are supposed to be owing to the presence of a peculiar substance, first noticed by Derosne, and by Serteurner, but proved by Robiquet to be a distinct vegetable principle, to which he gave the name of *narcotin*. It is obtained by evaporating the aqueous solution of opium to dryness, digesting the residue with ether, and evaporating, by which it is deposited in slender crystals.

Narcotin is insoluble in water, but it is dissolved by ether and by alcohol, though in the latter with difficulty. Though not soluble in water, yet if an acid be present it is dissolved, and as in opium there is always free acid, it is taken up in the watery infusion. Acetic acid seems to act on it, and deprive it of some of its properties; and hence, probably, its effect in preventing the disagreeable symptoms attendant in some individuals on the use of opium.

Though not apparently possessed of alkaline properties, yet in many respects it resembles those of the vegetable kingdom. Thus, it unites with, or at least is acted on by acetic acid, and so far deprived of its properties; and it contains nitrogen, which is the case with vegetable alkalies, (An. de Ch. xlv. An. de Ch. et de Ph. v. xxiv. xxxix.)

Caffein.

Caffein was discovered in Coffee, by Robiquet, and also by Pelletier and Caventou. It is soluble in water

and in alcohol. It may be volatilized by heat without undergoing decomposition. It has been analysed by Pelletier and Dumas, who found it composed of,

carbon,	46.51
oxigen,	27.14
hydrogen,	4.81
nitrogen,	21.54

In containing nitrogen, it differs from most other vegetable principles, but in this respect it resembles vegetable alkalies, to which class it was at one time thought to belong, but it has been shewn by Robiquet, not to be possessed of alkaline properties, (An. de Ch. et de Ph. xxiv.)

Lupulin.

By beating and sifting hops, *(humulus lupulus,)* an impalpable yellow powder is obtained, in which, according to Dr Ives, the active property resides. Though probably containing a distinct principle, it is not to be considered pure, tan, wax, resin, and other substances existing in it, (An. of Ph. N. S. 1.)

Asparagin.

By evaporating the juice of asparagus, Robiquet and Vauquelin obtained minute crystals, which, when purified, by repeated crystallizations, became colourless. Considering it the principle in which the properties of the plant reside, they gave it the name of *asparagin.* When heated, it undergoes decomposition, giving the odour of burning animal matter, probably, therefore, containing nitrogen. It is soluble in water, the solution not affecting acid or alkaline tests. It is not precipitated by acetate of lead, (An. de Ch. lvii.)

Piperin.

Pelletier has found that black pepper may be made to yield a peculiar principle, to which he has given the

name of *piperin*. It is obtained by evaporating an alcoholic solution to dryness, washing the residue with water, redissolving in warm alcohol, and evaporating, by which crystals are obtained. Though they have at first a pungent taste, they lose it by repeated solutions and crystallizations; so that they are not to be considered as the active principle of pepper, (An. de Ch. et de Ph. xvi.)

Colycintin.

Vauquelin found, that by evaporation of the alcoholic solution of colocynth, a yellow substance was deposited, which he considered the principle peculiar to the plant, and therefore gave it the name of *colycintin*. It is sparingly soluble in water, but easily dissolved by alcohol, and alkaline fluids. Its alcoholic solution is not precipitated by acetate of lead, (Quarterly Journal, xviii.)

Olivile.

When the gum of the olive tree is dissolved in alcohol, and the solution concentrated by evaporation, white needle-formed crystals are deposited, and to which Pelletier has given the name of *olivile*. It is sparingly soluble in water, but easily dissolved by alcohol; acetate of lead forms a precipitate when added to its aqueous solution, (An. of Ph. xii.)

Sarcocoll.

Sarcocoll is an exudation from the *pœnea sarcocolla*, a native of Ethiopia. It is in small round grains of a pale red or yellowish colour, having a sweetish taste. It is soluble in water and in alcohol, forming an adhesive solution. It is precipitated by tan, which is sufficient to distinguish it from gum, (An. de. Ch. lxxii.)

Ulmin.

This vegetable principle was first discovered by Klap-

roth, in an exudation from a species of elm, brought from Palermo; and according to Berzelius, it exists in many other trees, particularly in the bark, from which it may be prepared by maceration in alcohol, and washing the insoluble matter first with cold, and then with warm water. The last contains the ulmin along with an alkaline carbonate, from which it can be precipitated on the addition of an acid. It is a dark brown substance, sparingly soluble in water and in alcohol, but easily dissolved by solution of alkaline carbonates, (An. of Ph. 1.)

Inulin.

The roots of the *inula helenium* or *elecampane*, of the *colchicum autumnale*, of the *anthemis pyrethrum*, and some others, contain a peculiar principle, originally discovered by Rose in the first named plant; and hence called *inulin*. It may be procured by filtering a decoction of the roots, and allowing it to remain at rest for some time, by which a white powder is deposited. It is insoluble in cold, but dissolved by hot water, from which it is separated as the solution cools. With iodine it gives a yellowish precipitate. It is converted to oxalic and malic acids by the action of nitric acid. Sulphuric acid dissolves it without decomposition, as it may be precipitated from the solution by ammonia. It is thrown down from its warm watery solution by tannin, and the precipitate is redissolved by water, but not till it reaches its boiling point. These properties are sufficient to distinguish it from gum and from starch, (An. de Ch. xciv. and An. de Ch. et de Ph. xiv.)

SECTION III.

VEGETABLE ACIDS.

VEGETABLE ACIDS may be divided into two classes;—1*st*, Those that exist already formed in vegetables, and require merely the addition of some re-agent to separate them from the substances with which they are united; 2*d*, Those that are formed by the decomposition of vegetable matter. To the former belong

Tartaric,	Citric,	Benzoic,	Mucic,
Oxalic,	Malic,	Gallic,	Kinic, &c.

To the latter,

Acetic,	Camphoric,	Succinic, &c.

ACETIC ACID.

When the product of the acetous fermentation (p. 156.) is subjected to distillation, a transparent colourless fluid is obtained, having a fragrant odour, and an acid taste. It is acetic acid in a state of dilution, but containing also vegetable matter, which is apt to make it become mouldy. When *distilled vinegar*, as this fluid is called, is exposed to cold, the acid may be obtained in a greater state of concentration, but by no means so much so as that got from other sources; hence other methods are followed, by which it is procured concentrated, and with much less trouble. These will be mentioned, after having described the properties of its compounds.

Acetic acid is a transparent colourless fluid, having a strong acid taste, and a pungent odour. When applied to the skin for some time, it acts as a blister. When ex-

posed to cold, it freezes; but the point of congelation varies according to its strength.

The strong acid congeals at about 38, forming crystals, which liquefy at 40. When of sp. gr. 1063, it becomes solid at 55, and remains so even at 70.

The specific gravity of this acid is not, however, a proof of its strength, because, during the different processes followed for obtaining it, part of it is decomposed, and gives rise to the formation of other products. The only means of ascertaining its strength, is by finding the quantity of alkali necessary for its saturation.

When acetic acid is exposed to the air, it gradually evaporates; but, if the temperature be a little elevated, the evaporation goes on quickly. If the heat be high it is inflamed; and, during its combustion, it generates water and carbonic acid.

When passed through incandescent tubes, it is decomposed; and it is converted also into the usual products of vegetable matter, when heated with chlorate of potass, and with oxid of copper, as in the experiments of Gay Lussac and Thenard, and of Berzelius, made with the view of finding the proportions of its ingredients. As the acid itself contains water, the only way to arrive at its composition, is to decompose one of its salts, and from which the water can be easily expelled. The results of the analyses are:

	Gay Lussac.	Berzelius.	probably
carbon,	50.224	46.83	4 atoms
oxigen,	44.147	46.82	3 atoms
hydrogen,	5.629	6.36	2 atoms

and if so, its atomic weight is 62.5.

Acetic acid has a strong attraction for water, with which it unites, and, during its union, evolves caloric. The sp. gr. of the fluid varies according to its state of dilution; but its strength cannot be ascertained in this way, the density by no means depending on the quantity of water.—In the Appendix is given a table of the proportions of acid and water, in fluids of different gravity.

Acetic acid unites with the salifiable bases, and forms salts called *acetates*.

Acetate of potassa, formerly called *diuretic salt*, *regenerated tartar*, *and foliated earth of tartar*, is usually in soft foliated crystalline pieces, having a sharp taste, and extremely deliquescent, becoming fluid by exposure to air for a very short time. When heated strongly in close vessels, it is decomposed, carburetted hydrogen, carbonic acid, and an acidulous fluid, come off, leaving charcoal and carbonate of potass. It is soluble in about its own weight of water at 60, and yields a transparent solution, but which becomes mouldy by keeping.

According to the experiments of Wenzel, the dry salt is composed of

acid,	49.85	1 atom,
potassa,	50.15	1 atom.

Dr Thomson found the crystallized salt to contain 1 atom of salt, and 2 of water.

Acetate of potass is always obtained by the addition of sub-carbonate of potass to distilled vinegar, or pyroligneous acid, evaporating the solution, exposing the residue to heat to melt it, again dissolving and evaporating.

Acetate of soda is similar, in most of its properties, to the preceding, and is prepared in the same way. It is not deliquescent. When heated it undergoes decomposition, the acid giving off the same products as those from acetate of potass.

It is a compound of

acid,	61 or 1 atom,	
soda,	39	1 atom;

and in its crystallized state it contains 1 atom of salt, and 6 of water.

Acetate of *ammonia*, prepared in a similar manner, has been long known by the name of *spirit of mindererus*, and is used largely in medicine as a diaphoretic. It has a sweetish bitter taste; is deliquescent, and soluble in water. It differs from the preceding acetates, in being easily volatilized by heat, and condensing unchanged in its properties. The crystals consist of 1 atom acid, 1 of base, and 7 of water.

Acetic acid unites with the earths and forms salts,

most of which are of very little interest; indeed, the only ones that claim attention, are those of baryta and of alumina.

Acetate of baryta may be prepared by the addition of the acid to the artificial carbonate, or to the sulphuret, procured by the decomposition of the sulphate by charcoal, (vol. I. p. 478.) By evaporation of the solution, crystals are obtained, which are efflorescent, and soluble in about their own weight of water. It is decomposed by the alkalies, and by their carbonates and sulphates; and hence its use as a test, particularly of sulphuric acid. *(See Mineral Waters.)*

Acetate of alumina is a very important salt. It cannot be prepared by the direct union of its ingredients, the attraction between them being too feeble; but it is easily obtained by decomposing an acetate, as that of lead, by alum, by which sulphate of lead is deposited, and acetate of alumina is held in solution.

A curious circumstance has been noticed by Gay Lussac with respect to this acetate. When its solution is heated, even in close vessels, a considerable part of the earth is deposited, but is re-dissolved when the temperature falls.

Acetate of alumina is employed abundantly as a mordant. *(See Dyeing.)*

Acetic acid acts on some of the metals, as iron, copper, zinc, tin, and lead, and oxidizes them. With the oxids of those on which it does not act, it may be made to unite by decomposition of their salts.

Acetate of iron is prepared by dissolving the metal in the acid, or by the addition of green vitriol to acetate of lead. The solution is of a brownish red colour, and does not crystallize on evaporation. It is used in calico-printing, being more easily acted on than any of the other salts of iron by the different re-agents employed in striking colour.

Acetates of copper. Acetic acid acts slowly on copper, first oxidating it, and then uniting with the oxid, forming *verdigris*, which is an *acetate*. It is prepared by

covering sheets of copper with the husks of grapes, which, after the juice has been expressed, have been allowed to run into the acetous fermentation. After remaining for some days excluded from air, the mixture is moistened, and the copper gradually becomes covered with a crust, which, when scraped off, is dried by exposure to sunshine.

Verdigris, as thus prepared, is of a greenish colour, with a slight tinge of blue. It is partly soluble in water, owing to a change it undergoes, and by which it is converted into two salts, a soluble super-acetate, and a sub-acetate, deposited in the form of a greenish powder.

Acetate of copper is composed, according to Ure, (An. of Ph. N. S. iv.) and Berzelius, of

acetic acid,	28.30,	1 atom,
peroxid copper,	43.25,	1 atom,
water, -	28.45,	6 atoms.

The above is the composition of the crystallized acetate; but that of commerce contains only about 25 per cent. of water, and in general from 1 to 2 per cent. of impurities.

When acetate of copper is dissolved in acetic acid, it is converted into a *bin-acetate*, composed of

acid, -	2 atoms,
oxid, -	1 atom,
water, -	3 atoms.

It is soluble in water, and crystallizes in oblique rhombic prisms. It has a disagreeable metallic taste, and acts as a poison. When exposed to heat, it is decomposed, and acetic acid is disengaged.

Sub-acetate of copper is prepared by washing verdigris repeatedly, till the water comes off colourless. It is a greenish powder, composed of 1 atom acid, and 2 atoms of oxid.

The acetates of copper are used as dyes, and they are employed also in medicine, as escharotics. They are sometimes also decomposed, with the view of preparing acetic acid.

Acetates of lead. Acetic acid acts slowly on lead, first

oxidating it, and then converting it to a salt. Two compounds have been observed, an acetate and sub-acetate.

Acetate of lead, long known by the name of *saccharum Saturni*, or *sugar of lead*, is formed by dissolving the carbonate in acetic acid. For this purpose, thin sheets of lead are partly immersed in vinegar, kept at a slightly elevated temperature, by which the vapour is gradually decomposed, giving rise to the formation of oxid of lead and carbonic acid, so that the upper part of the metal is ultimately covered with carbonate. When this is done, it is immersed in the vinegar, and the clean surface exposed, which, in its turn, acquires a coating of carbonate, while that in the fluid is dissolved. In this way, by subjecting the lead to the action alternately of the vapour and of the acid itself, it is completely converted to acetate. The solution, after filtration, may be made to yield crystals, but the salt is generally obtained in the form of a crystalline mass, resembling loaf sugar in its appearance.

Acetate of lead is soluble in about 20 parts of water; but it is necessary to use it distilled, otherwise there is a slight decomposition, owing to the super-carbonate of lime always existing in common water. Should common water be employed, the transparency is easily restored by the addition of a few drops of acetic acid. The solution is decomposed by those acids which will form with the oxid insoluble compounds, as sulphuric, phosphoric, and muriatic, and by sulphates, phosphates, muriates, and carbonates. The decomposition by sulphuric acid is important, as affording a means of preparing acetic acid.

Acetate of lead is composed of

acetic acid,	26.97	1 atom,
yellow oxid,	58.71	1 atom,
water,	14.32	3 atoms.

It is used chiefly by dyers and calico-printers in the preparation of some of their mordants, as acetate of alumina, (see p. 226.) It is employed also in medicine as an astringent wash.

Sub-acetate of lead is prepared by boiling 100 of ace-

tate with 150 of litharge, reduced to fine powder, by which a transparent colourless solution is formed, well known by the name of *Goulard's Extract.* By evaporation, tabular crystals may be obtained. It has a less sweet taste, and is not so soluble as the acetate. Its solution is decomposed by gum, and hence it is employed as a test of this vegetable principle, (p. 165.) It consists of 1 atom of acid and 3 of oxid.

Acetate of zinc is employed as a mild astringent wash, and is therefore a pharmaceutical preparation. It is procured by dissolving 3 parts of sugar of lead, and 4 of sulphate of zinc, each in 240 of water, and mixing them, by which sulphate of lead is precipitated, and acetate of zinc held in solution, and is procured by filtration.

Acetic acid acts on several of the vegetable principles. It dissolves gluten, the volatile oils, camphor, resins, and gum resins, without decomposing them; for, on the addition of an alkali, they are precipitated unchanged in their properties.

Acetic acid acts with alcohol, and generates an etherial fluid. It is prepared by the distillation of equal parts of acid and spirit, returning the product into the retort, and repeating the distillation four or five times, adding a little carbonate of alkali, in the last distillation, to prevent any acid from coming off.

Acetic ether has a pleasant odour; its sp. gr. is 866; its boiling point 128. It burns with a yellowish flame, and yields acetic acid during the combustion, though this cannot be detected in the ether itself. Water dissolves about 1-7th of its weight of it.

Acetic acid is generally obtained from some of the acetates. Three different methods of effecting the decomposition are followed. 1*st*, By heat; 2*d*, by sulphuric acid; 3*d*, by a sulphate.

Bin-acetate of copper is easily decomposed by heat, and is therefore usually employed for yielding the acid in this way. For this purpose, any quantity is put into a retort, and a slight heat applied, the vapour

being condensed in a receiver. What comes over first, being impure, must be rejected; the remainder has a strong pungent taste, but a slight greenish colour, owing to the presence of impurities, from which it may be freed by cautious re-distillation. The product is of sp. gr. from 1056 to 1080, the lightest being obtained towards the end of the process. If in the preparation of the acid in this way, different receivers be employed, so as to collect the product at the different stages of the process, that last obtained, and which is of light specific gravity, is found to contain little acid. By the addition of potassa, and re-distillation, it yields, according to Derosne, (An. de Ch. lxiii.) an etherial fluid, to which he has given the name of *hydro-acetic ether*, and which seems to be formed by the decomposition of the acid.

Hydro-acetic ether may also be procured from other acetates, as that of lead. It is volatile and combustible. It is dissolved by water, alcohol, and oil, both essential and unctuous. Its sp. gr. according to Maccaire and Marcet, is only 786. Its boiling point 138.

Since this etherial fluid is so easily generated by the distillation of acetates, it is evident, that to get a strong acetic acid, the first and last portions of the product of the distillation ought to be rejected.

Acetic acid may also be procured by the decomposition of an acetate by sulphuric acid. Acetate of lead, of potass, or of soda, is commonly employed. The alkaline acetates with a half, or the metallic one with a fourth of its weight of sulphuric acid, is placed in a retort, and distilled by a slight heat till it ceases to give off vapour. Acetate of soda or potass is easily prepared for this purpose, by mixing sulphate of soda and acetate of lead, filtering and evaporating to dryness. The acid obtained by these processes, contains a little sulphurous acid, from which it is freed, by re-distillation from black oxid of manganese, or from acetate of lead.

Lastly, acetate of lead may be decomposed by sulphate of iron, which is the process given in the Edinburgh

Pharmacopœia, with the view of preparing the *acidum aceticum forte*. One pound of dried sulphate is mixed with ten ounces of acetate, and distilled by heat cautiously applied. In this instance, the sulphuric acid and oxid of lead unite, while the acetic acid, owing to the heat, is prevented from uniting with the iron, it therefore comes over in vapour; but as thus procured, it is by no means so strong as that prepared by the other processes, and it has also a disagreeable empyreumatic odour, from which it is difficult to free it.

The acid obtained by the two first processes, may be purified by repeated distillation, and by subjecting the product to cold so as to congeal it. The solid matter, when freed by straining from the unconsolidated part, and melted, contains about 80 per cent. of real acid.

Acetic acid is now procured in great abundance, in a state of dilution, however, by the distillation of wood, from which it comes over mixed with tar, and is purified by repeated distillations, and filtration through animal charcoal. It is in this state, and under the name of *pyroligneous acid*, that it is now employed in the preparation of the different acetates used in the arts, (p. 158.) The strong acid is employed chiefly as an aromatic, being mixed with oil of cloves and camphor. It is used also as an escharotic, particularly for removing warts.

Tartaric Acid.

The substance deposited from wine, called *tartar*, has been long known to contain a peculiar acid, in union with potassa, which was formerly called *tartarous*, but now *tartaric* acid. Scheele first pointed out the method of obtaining it pure, by the decomposition of tartar by means of lime. For this purpose the tartar is dissolved in water, and to the solution, after filtration, carbonate of lime is added, till it ceases to redden litmus, by which the lime is deposited in union with the excess of acid existing in the tartar.

The precipitate, when washed and dried, is mixed with half its weight of oil of vitriol, by which sulphate of lime is formed, and tartaric acid set at liberty; and as the former is sparingly soluble, the latter is procured by filtration, and by evaporation may be obtained in crystals. To ascertain if it is free from sulphuric acid, add to its solution that of acetate of lead, by which a white precipitate is formed. If this is entirely soluble in nitric acid, it is pure tartrate of lime; but if only partly soluble, it is a mixture of tartrate and sulphate, shewing that the acid is contaminated with sulphuric acid. To remove this, it must be mixed with an additional quantity of tartrate of lime, by which the earth and sulphuric acid will combine, and thus leave the tartaric acid pure.

The crystals of tartaric acid vary in form according to the mode of preparation. When heated to about 212 they melt, and at 250 begin to boil and pass off in vapour. When the temperature is high, they undergo decomposition, an acid called *pyro-tartaric* and an oily fluid are condensed in the receiver, carburetted hydrogen and carbonic acid gases are disengaged, and carbon remains in the retort. Tartaric acid, therefore, contains the usual ingredients of vegetable matter. The experiments of Berzelius and Dr Ure, made with the view of ascertaining the proportions, very nearly agree. The results are,

	Berzelius.	Ure.	Probably	
carbon,	35.98	31.42	4 atoms	= 36.36
oxigen,	60.28	65.82	5 do.	= 60.61
hydrogen,	3.74	2.76	2 do.	= 3.03
	100.00	100.00		100.00

If the above is correct, the atomic weight of tartaric acid is 82.5.

The crystallized acid seems composed of an atom of acid and of water.

Tartaric acid is very soluble in water, so much so, that a solution of a thickish consistence can be formed,

which is not apt to become mouldy unless when diluted.

By digestion in nitric acid, Hermstaedt found that it was converted to oxalic acid.

Tartaric acid unites with bases, and forms *tartrates*, and it has also the property of forming triple compounds with the alkalies and metallic oxids.

Tartrates of Potassa. There are two compounds of tartaric acid and potass, a tartrate and bi-tartrate.

Bi-tartrate, commonly called *super-tartrate* and *cream of tartar*, has been long known as a distinct salt. It is procured from crude tartar by solution, filtration, and evaporation, by which crystals may be procured; or by continuing the evaporation, it is separated in the form of powder, which during the ebullition rising to the surface is skimmed off, and hence the name *cream* of tartar.

It has a sour though not unpleasant taste. When heated it undergoes complete decomposition, and is converted to carbonate of potass, mixed with charcoal, while at the same time olefiant gas and an acidulous fluid are disengaged. All of these, except the potassa, are the products of the decomposition of the acid, the olefiant gas being formed by the union of part of its carbon and hydrogen, the acidulous fluid, by the combination of carbon, oxigen, and hydrogen, while the carbonic acid is produced by the carbon uniting with oxigen. The residue of this process is commonly called *black flux*, being much employed in chemical analysis. As it contains carbonate of potass, the decomposition constitutes the process for procuring the *carbonas potassæ purissimus* of the Pharmacopœia, and which consists merely in burning cream of tartar in a ladle, till it ceases to give off fumes, dissolving the residue, filtering and evaporating to dryness, by which a white pulverulent salt is obtained, and hence the name *salt of tartar*, frequently given to it.

Super-tartrate of potass is sparingly soluble, requiring about 60 of cold, and 30 of boiling water to dissolve it. The solution has a sour taste, and reddens vegetable blues.

When, instead of burning super-tartrate alone, it is deflagrated with nitre, the product is the same, more of the carbon being converted to carbonic acid, to unite with the potassa. This process is also followed in the preparation of black flux, and of carbonate of potass.

Super-tartrate is, according to Berzelius, composed of

acid,	70.45	or 2 atoms
potass,	24.80	1 do.
water,	4.75	1 do.

It is used in medicine as a gentle laxative, and in solution as an acidulous drink. It is employed for yielding its acid, and the other compounds containing it.

Tartrate of potass is prepared from the bi-tartrate, either by the removal of the excess of acid by lime, as in the first part of the process for procuring the acid, (p. 231.) or by neutralizing it by carbonate of potass; and when this last is followed, it is best to have the alkaline carbonate in solution, and add the cream of tartar to it, because little water is required, and of course evaporation is saved. It is obtained in flat prismatic crystals, containing 2 atoms of water, and 1 of salt, composed of an atom of acid and alkali, or just half the acid that exists in the super-tartrate.

It is much more soluble than the preceding, requiring only about its own weight of water to dissolve it, and hence called *soluble tartar*. It is decomposed by heat, and converted to carbonate of potass. The acids deprive part of it of its potass, and the acid set free, unites with the remainder to form super-tartrate.

Tartrate and *super-tartrate of soda* are both soluble, and hence tartaric acid is employed as a means of distinguishing potassa from soda, when an alkaline matter has been detected in a fluid. *(See Mineral Waters.)*

Tartrate of potassa and soda may be formed by the neutralization of the excess of acid in cream of tartar, by carbonate of soda. It has been long known by the name of *Rochelle salt*. It is soluble, requiring about 5 of cold, and much less of boiling water, to dissolve it. It is com-

posed of 1 atom of tartrate of potass, and 1 of tartrate of soda, or 54 to 46.

Tartaric acid unites with the earths; the only salt of any consequence is

Tartrate of lime, as from it tartaric acid is procured. It is formed as already described, (p. 231.) by the addition of carbonate of lime to super-tartrate of potass. It is sparingly dissolved by water, but an excess of acid renders it more soluble. It is composed of 1 atom acid, 1 atom lime, 4 atoms water.

Tartaric acid acts on some of the metals, as iron, zinc, and mercury. The alkaline tartrates cause precipitation with some of the metallic salts, as with those of gold, platinum, silver, &c.

The only compound of any interest, containing an oxid of the common metals, is that with antimony, and which, besides tartaric acid and oxid of antimony, contains also potass, so that it is a triple salt.

Tartrate of antimony and potass, long known by the name of *tartar emetic*.—Various processes have been recommended for procuring this salt. They all consist of two parts: 1*st*, procuring an oxid of antimony; 2*d*, causing this oxid to unite with the acid and potass. The methods of preparing the oxid have been already described, (p. 64. & 68.) The second part of the process is the same in all the pharmacopœias. It consists merely in boiling the oxid along with super-tartrate of potass, the excess of acid of which is neutralized, and thus the triple salt is formed. Being soluble, it is taken up by the water and deposited when the solution cools in the form of transparent colourless tetrahedral crystals.

In the preparation of tartar emetic, the Edinburgh College uses the oxid prepared by deflagrating the sulphuret with nitre; the London orders the oxid procured by roasting the sulphuret; and the Dublin, the precipitate from the muriate by the affusion of water, which, when dried, is also oxid. The last is by far the best process, as not only least troublesome, but affording the salt freest from impurities, for in the other ways of preparing the oxid,

the iron and lime always existing in the sulphuret, are dissolved by the tartaric acid, and are deposited during the crystallization, whereas the antimonial oxid precipitated by the Dublin process, is free from impurities.

Tartrate of antimony and potass is decomposed by heat. It is soluble in about 14 of cold, and in 2 of boiling water; but it is difficult to keep it in solution; it very soon becomes mouldy from the decomposition of the acid; and hence the orders given in the pharmacopœia for having it dissolved in wine, (antimonial wine,) in which it may be kept without undergoing any change. The watery solution is decomposed by hydro-sulphurets, which throw down an orange-coloured hydro-sulphuret of the oxid, and by ammonia, which precipitates the oxid pure.

According to Thomson, (First Pr.) tartar emetic is composed of,

tartaric acid	2 atoms	= bitartrate of potass	57.38
potassa	1 do		
protoxid antimony	3 do	= oxid of antimony	42.62

with which the analysis of Phillips, (An. of Ph. ix.) very nearly agrees.

According to the former, the crystals contain 1 atom of salt and 2 of water; but according to the latter, 1 to 3.

Tartrate of antimony and potass is employed in medicine as an emetic and diaphoretic, for both of which purposes it is well adapted.

Tartaric acid is used chiefly by calico-printers in the preparation of some of their mordants. It is employed by chemists, principally as a test of potassa.

It has been mentioned, (p. 232.) that when supertartrate of potass is exposed to heat in a retort, an acidulous fluid is given off, and a white crystalline matter is deposited on the neck of the vessel. This, with the fluid, contains a peculiar acid called *pyro-tartaric*, which may be procured from the latter by evaporation. It has a sour taste, and may be sublimed without undergoing decomposition. It is soluble in water, and its so-

lution does not precipitate some of the metallic salts which are decomposed by tartaric acid, nor does it form a sparingly soluble compound with potassa,—properties sufficient to distinguish it from that acid ; and as acetate of lead is decomposed by it when in union with an alkali, it is altogether different from acetic acid.

Oxalic Acid.

The leaves of sorrel, particularly of the *oxalis acetosella*, when expressed, yield a juice, which contains potassa in union with an acid of a peculiar nature called *oxalic*, from which it can be obtained in its uncombined state ; but it is seldom prepared in this way. It has been already repeatedly mentioned, that vegetable bodies, in general, yield oxalic acid, when treated with nitric acid ; and hence the method usually followed in procuring it. For this purpose sugar is generally employed. Six ounces of nitrous acid are poured on an ounce of loaf sugar, placed in a retort having a receiver adapted to it, and kept cold ; a slight heat is applied, but removed when the action commences ; and after it has ceased, it must be renewed to distil off a part of the fluid. The residue, while hot, is poured into an evaporating basin, and, when cold, crystals of oxalic acid are deposited, which must be purified by solution and re-crystallization.

During the preparation of the acid, a large quantity of nitric oxid is disengaged, which, combining with the oxigen of the air in the apparatus, is condensed in the form of nitrous acid ; and hence the necessity of adapting a receiver, not only to prevent the escape of the noxious fumes, but also to lessen the expense of the process. Carbonic acid gas is also disengaged. 100 parts of sugar yield about 50 of acid.

Oxalic acid is obtained in small prismatic crystals, very much resembling those of sulphate of magnesia ; for which, indeed, it has been frequently mistaken ; and as it acts as a most virulent poison, fatal accidents have

occurred from its having been taken instead of Epsom salts. From this, however, it is easily distinguished by its acid taste, or by its exciting effervescence when added to carbonate of potass or of lime.

The crystals of oxalic acid are soluble in about 15 of cold, and in their own weight of water at a boiling heat. The solution is transparent and colourless, has an extremely sour taste, and reddens vegetable blues; 1 of acid dissolved in 3600, being sufficient to affect litmus paper.

When oxalic acid is exposed to heat, part of it sublimes undecomposed, the remainder comes off in the form of gaseous products, leaving charcoal in the retort. By returning the sublimed matter into it, and repeating the application of the heat, the whole may be destroyed; but it is difficult to ascertain the proportion of its ingredients in this way, not only from the imperfect decomposition of the acid, but also from the difficulty of getting it free from water. It has been analyzed when in union with a base, in which state it may be obtained quite anhydrous. The results of the analyses by Gay Lussac and Thenard, and by Berzelius, are very nearly the same:

	Thenard.	Berzelius.
carbon,	33.217	33.222
oxigen,	66.290	66.534
hydrogen,	.493	.244.

In these results the quantity of hydrogen is not sufficient to make up an atom, which led to the suspicion that it was foreign; and that, accordingly, oxalic acid did not contain any; an opinion at first advanced by Dobereiner, and proved satisfactorily by the experiments of Ure, (Ph. Tr. 1822,) and of Thomson, who agree in making it a compound of

carbon, 33.34 or 2 atoms = 15
oxigen, 66.66 3 atoms = 30 } = 45;

or its composition may be thus stated;

carbonic acid, 1 atom 27.5
carbonic oxid, 1 atom 17.5 } = 45.

Oxalic acid differs, therefore, from other vegetable acids, in not containing hydrogen, and since sugar,

from which it is formed, has the three usual ingredients of vegetable matter, we can easily account for the changes accompanying its formation; for, since nitric oxid is given off along with carbonic acid, oxigen must be taken from the nitric acid, and consumed in removing part of the carbon, and the whole of the hydrogen of the sugar that has been converted into oxalic acid.

Oxalic acid, in its crystallized state, contains, according to Thomson, no less than 50 per cent. of water, being a compound of 1 atom acid and 4 of water.

Oxalic acid unites with bases, and forms *oxalates;* and it has the property also of forming triple salts

Oxalates of potass. Oxalic acid forms three salts with potassa; an oxalate, a bin-oxalate, and quadr-oxalate. The only one of any interest is the second.

Bin-oxalate of potass exists native in the leaves of the *oxalis acetosella*, and *rumex acetosa*, from which it may be procured by expression; but it is obtained more easily by the addition of the acid, in excess, to the carbonate of the alkali, by which minute crystals are deposited. It has an acid taste, and is soluble in about 60 parts of water. The solution is much employed for removing iron stains from cloth, the excess of acid uniting with the oxid of iron, and forming a soluble compound. For this purpose, it is sold under the name of *salt of sorrel*, or *essential salt of lemons*, being disguised by the addition of essential oil of lemons. In removing iron stains, the cloth, after being wetted, is rubbed over with the salt, which is left on for some time, and then washed off. Should the stain not be removed, the process must be repeated.

The three oxalates of potass are composed of

	Oxalate.	Bin-oxalate.	Quadr-oxalate.
acid,	43 or 1 atom,	60 or 2	75 or 4
bases,	57 1 atom,	40 1	25 1

Oxalate of ammonia, formed by the neutralization of the acid by carbonate of ammonia, is an important compound, being much employed in analysis, with the view

of detecting lime. It may be procured in the form of crystals, but it is generally kept in solution. It is a compound of 1 atom of acid, and 1 of base.

Oxalate of lime may be formed by the addition of oxalic acid to lime water, or of an oxalate to a salt of lime, by which a white powder is precipitated. It is insoluble. When heated to redness, it is decomposed, and converted to carbonate of lime; and, if the heat be intense, the whole of the acid is expelled, and pure lime is left. It is composed of

acid,	1 atom or	43.75
lime,	1 atom	56.25

From the ease with which oxalic acid, and its compounds, act on lime, they are employed to detect it; and the test is so extremely delicate, that it will indicate its presence though dissolved in at least a million parts of water, *(See Mineral Waters.)*

Oxalate of magnesia is soluble in water; accordingly, when a solution of oxalate of ammonia is mixed with a fluid containing calcareous and magnesian salts, the former only is precipitated, and hence a good method of separating lime from magnesia when together in solution.

Oxalic acid acts on some of the metals. It unites with their oxids and forms salts, most of which are insoluble. When these are exposed to heat, they are decomposed, and, in some instances, the metal is left in its metallic state, as is the case with those which are neutral, and contain protoxid; because, as the acid requires but 1 atom of oxigen to convert it to carbonic acid, the oxigen from the base passes to it, and carbonic acid and metal are the result. Hence the method of procuring some of the metals in their metallic form, particularly those obtained with difficulty from the substances with which they are usually mixed.

Oxalic acid, it has been already noticed, exists in a state of combination in the leaves of sorrel. It is found also in union with lime in different plants, particularly those of the cryptogamious class. It is supposed that oxalate of lime may bear the same relation to cryptogamia that

carbonate of lime does to corals, and phosphate of lime to bones.

Oxalic acid is used for cleaning boot tops; and as it acts easily on oxid of iron, and forms a soluble compound, it is employed for removing iron stains and ink spots from cloth, being used in the same way as the salt of lemon, (p. 239.)

Citric Acid.

Citric acid exists in considerable quantity in the juice of limes and of lemons, *(citrus medica,)* and from which it is always obtained by the process originally recommended by Scheele. For this purpose, the juice, after filtration, is heated, and mixed with chalk as long as there is any effervescence, weighing the quantity employed. Citrate of lime is deposited, and is to be washed repeatedly with cold water, after which it is to be mixed with sulphuric acid, equal in weight to the chalk used, and diluted with about 10 parts of water, stirring the mixture constantly, to bring the whole of the citrate in contact with the acid, and prevent the vegetable acid liberated from being decomposed. Sulphate of lime is deposited, and citric acid held in solution, and is separated by filtration. The fluid is then to be evaporated by the application of a slight heat, by which crystals are obtained; but they require to be frequently dissolved and crystallized, to free them from colouring matter. In conducting this process, iron vessels must be avoided, nor should iron instruments be used to stir the mixture, because the acid acts so easily on it, and acquires a brownish colour, (Parke's Chem. Essays.)

Citric acid, as thus obtained, is in regularly formed, transparent, octohedral, and sometimes rhomboidal prismatic crystals, soluble in less than their weight of cold, and in half their weight of boiling water. The solution has a sour taste, reddening vegetable blues; but it is apt to become mouldy when kept. The crystals do not suffer any change by exposure to air. When heated, they

lose their water of crystallization, and are decomposed, even before the whole is expelled; hence, in ascertaining the proportions of the ingredients by destructive distillation, it is necessary to employ one of its salts. It has been analyzed by Gay Lussac, Dr Ure, Berzelius, (An. of Ph. v.) and Dr Thomson, (First Pr.) the results of the two last very nearly agreeing. They are,

	Berzelius.	Thomson.			
carbon,	41.369	41.379	=	4 atoms,	=72.5
oxigen,	54.831	55.173	=	4 atoms,	
hydrogen,	3.8	3.448	=	2 atoms,	

The crystals contain 1 atom of acid and 2 of water.

Nitric acid decomposes it, converting it first to oxalic, and if the action be continued with more nitric acid, acetic acid is generated.

Citric acid forms with salifiable bases salts called *citrates*. Those of the alkalies are soluble; of the earths, in general insoluble. Some of the metals are easily acted on by it. Iron and zinc, for instance, are dissolved with effervescence, and converted to citrates. When iron filings are kept in the acid, a solution is formed, which gradually deposits a white powder, consisting of proto-citrate, but which, by the absorption, becomes per-citrate, of a brownish colour.

An alkaline citrate precipitates many of the metals from their solution, as lead, silver, &c.

Citric acid, or rather lime juice, is employed as an acidulous drink, and in preventing scurvy. It is used also, either in the state of lime juice, or crystallized, in the preparation of effervescent draughts. For this purpose, equal weights of the powder of the crystals of citric acid, and of bi-carbonate of soda, are dissolved in separate portions of water, which, when the solution is completed, are to be mixed and instantly swallowed, so that the carbonic acid may be taken into the stomach.

Malic Acid.

Malic acid exists in the juice of apples, gooseberries, and many other fruits. Vauquelin found it in the juice of the common *house leek*, and Donovan in that of the *service tree*, (sorbus aucuparia,) and described it under the name of *sorbic* acid.

Different processes have been recommended for procuring it. They all consist in uniting it with a base, as with lead, which is afterwards to be separated by the addition of an acid, or of sulphuretted hydrogen. The process recommended by Donovan for procuring it from the juice of the service tree, and which will apply to the other substances in which it exists, is to add to the juice obtained from the berries by expression, and decolorized by filtration through charcoal, a solution of acetate of lead as long as it throws down a precipitate, which is malate of lead. Having washed this with cold water, to carry off colouring matter, it is then to be dissolved in boiling water, and the solution set aside to crystallize. The crystals are next to be mixed with sulphuric acid, using less than is requisite for their complete decomposition, by which sulphate of lead is deposited, and malic acid held in solution, and may be procured by filtration; and to remove any lead with which it may be contaminated, it is subjected to the action of sulphuretted hydrogen, and then boiled to expel the superfluous gas, and again filtered. The acid solution thus obtained, is generally of a pale brownish colour, but becomes colourless when purified by repeated solutions. On evaporation, it yields malic acid in the form of a thick syrup.

When malic acid is exposed to heat, along with oxid of copper, it is decomposed; and hence the method followed by Vauquelin in analyzing it. According to him, it is composed of

		Probably	
carbon,	28.3	3 atoms,	= 75
oxigen,	54.9	4 atoms,	
hydrogen,	16.8	10 atoms,	

It unites with bases, and forms *malates*, which have, however, been but little examined. Those containing the alkalies are soluble and deliquescent. Malates of lime, baryta, strontia, and magnesia, are soluble, but that with alumina is insoluble.

Malic acid acts on few of the metals, but it unites with the oxids, and forms compounds, most of which are insoluble.

Malate of lead is formed by the addition of the acetate to the acid, or to any of its soluble salts. It is easily decomposed by sulphuric acid, and hence its use in the preparation of the acid.

Besides the sources already mentioned, from which malic acid is procured, it may be also obtained by the action of nitric acid on sugar. It has been already mentioned, that the fluid from which the crystals of oxalic acid are procured, (p. 237.) consists partly of oxalic, partly of malic acid. To obtain it from this, lime is added, by which oxalate of lime is deposited, and malate of lime held in solution. After filtration, the malate may be precipitated by alcohol, and again dissolved in water, and decomposed by acetate of lead, and from the malate the acid may be obtained, as already described.

Malic acid is not put to any particular use.

Benzoic Acid.

It has been already mentioned, that balsams owe their peculiar fragrant odour to the presence of an acid called *benzoic*. From these it is procured in different ways. The simplest is to place any quantity of *gum benzoin* into a common subliming vessel, and apply heat; the balsam is at first melted, and a vapour arises, which is quickly condensed in the cool part of the apparatus, in slender silky crystals. They are benzoic acid, but rendered impure by the presence of a little volatile oil, to free it from which they may be dissolved in alcohol, and precipitated by water; or they may be taken up by an

alkaline solution, and thrown down by the addition of a weak acid.

The solution and precipitation constitutes another mode of procuring the acid. It is the one ordered by the Edinburgh College. For this purpose, 3 parts of benzoin are boiled with 1 of carbonate of soda, in successive portions of water, and the fluid filtered, by which benzoate of soda is obtained, and after concentrating by evaporation, diluted sulphuric acid is added as long as it throws down any precipitate, which is to be washed with a little cold water, and, when dried, sublimed to get it in crystals.

Benzoic acid, as generally obtained, is in soft needle-formed crystals, having a peculiar pleasant odour. When exposed to a moderate heat, it is sublimed and condensed, unchanged, in the cool part of the apparatus; but when the temperature is high, it is decomposed, and the usual products are given off. It is difficult, however, nay, almost impossible, to decompose it in this way, owing to its volatility. It has been analyzed by Berzelius and Ure, the former of whom seems to have given the most correct view of its composition. It is, according to him, composed of

				or rather
carbon,	74.41	=	5 atoms,	15,
oxigen,	20.43	=	1 atom,	3,
hydrogen,	5.16	=	2 atoms,	6,

because, by the decomposition of some of its compounds, the atomic weight has been found to be 150, a number according with the last view of its composition.

$7.5 \times 15 + 10 \times 3 + 1.25 \times 6 = 150$, (First Pr.)

Benzoic acid is sparingly soluble in water, requiring 24 parts, at a boiling heat, for solution, from which almost the whole is deposited, when the temperature falls.

It unites with the salifiable bases, and forms *benzoates*. The salts, however, present little of any interest. The benzoates of the alkalies, of lime, baryta, strontia, and alumina, are soluble. Those of the metals are in general also soluble, but that with iron is insoluble; and hence

Berzelius has proposed to use benzoic acid, or rather a benzoate, with the view of precipitating iron from any of its solutions, and thus ascertaining its quantity. The precipitate is of a brownish colour, supposing a per-salt to be employed, and after being dried at 212, is composed of 1 atom acid, 1 of peroxid, *i. e.* 15 to 5; so that 1-4th of its weight gives the oxid of iron existing in it. Benzoate of lead is insoluble, so that it is necessary to remove it, if present, by the addition of sulphate of soda, before adding the benzoate.

Benzoic acid is contained in all balsams, and in different plants. It has been found also in the urine of graminivorous animals, and in that of children. Its chief source is gum benzoin, or benjamin, the produce of the styrax benzoina, from which it is always obtained as already described.

It is used chiefly as an aromatic.

Gallic Acid.

It has been already mentioned, that tannin, as usually procured from nut-galls, contains also a peculiar acid called gallic, intimately connected with it, and nearly allied to it in many of its properties. It was first obtained in its insulated form by Scheele, but it had been previously examined, in union with tan, by other chemists.

The process followed by Scheele in preparing it, is extremely simple, and with some slight modifications recommended by Braconnot, (An. de Ch. et de Ph. ix.) is the one generally followed. For this purpose the galls are infused in water for some days, and the solution, after filtration, exposed in open vessels for several weeks, by which minute crystals are gradually deposited. By farther evaporation, and exposure to air, more crystals are obtained. These are next kept in boiling water for some time, to separate the acid from an insoluble matter with which it is mixed, and the solution by filtration, and exposure to air, yields crystals of gallic acid. As thus obtained, they are of a pale brown colour, but

by dissolving them, and passing the solution through animal charcoal, previously washed with muriatic acid, they may be procured transparent and colourless.

Gallic acid may be also obtained by sublimation from galls, as recommended by Deyeux, (Crell's Annals, 1.) or by precipitating the tan and extract from galls, by boiling with alumina, and then exposing the filtered fluid to air, (Nich. Journ. 1.) The tannin may also be previously thrown down by albumen, or by gelatin, the former derived from white of eggs, the latter from isinglass, (Quarterly Journal, VI.)

Gallic acid, when pure, is transparent and colourless. It has a sour unpleasant taste, and when heated strongly in air, is inflamed, and during its combustion emits an aromatic odour. Exposed to heat in close vessels, it is decomposed, and yields the usual products. It has been analysed by Berzelius, and found to contain, (An. of Ph. v.)

carbon,	56.64
oxigen,	38.36
hydrogen,	5.

It is not altered by exposure to air. It is soluble in about 24 parts of cold, and in 3 of boiling water. The solution is, however, slowly decomposed, acquiring a mould on its surface.

Nitric acid converts it to oxalic acid.

It unites with bases, and forms *gallates*. Those of the alkalies are soluble; with lime, baryta, and strontia, insoluble.

When the acid itself is added to the salts of glucina, ittria, and zirconia, it occasions precipitation, owing to the strong attraction existing between them.

It precipitates many of the metals from their salts. That with iron is black; with lead, white; copper, gold; and silver, brown. In the preparation of ink, already described, (p. 201.) the black precipitate must be considered to contain the oxid of iron, in combination not only with tannin, but also with gallic acid; for both of

these exist in the astringent matter employed in its manufacture.

Meconic Acid.

When an infusion of opium is boiled with magnesia, with the view of preparing morphia, *(See Vegetable Alkalies,)* and the narcotic principle has been removed by alcohol, an insoluble matter remains, which is a compound of the earth, and a peculiar acid, to which the name of *meconic* has been given, (μηκων, poppy.) To procure the acid from it, it is dissolved in diluted sulphuric acid, and by the addition of muriate of baryta, sulphate and meconate of baryta are precipitated. By dissolving the precipitate in warm diluted sulphuric acid, filtering and evaporating, crystals of meconic acid are obtained. An easier method of preparing it, has been lately recommended by Dr Hare, (Lond. Quarterly Journ. N. S. iii.) To an aqueous infusion of opium, add sub-acetate of lead, by which meconiate of lead is deposited, and from which, after being washed, the oxid may be removed by sulphuretted hydrogen, and the acid left in solution.

Meconic acid is soluble in water and in alcohol, the solution reddening vegetable blues. When exposed to heat, it undergoes decomposition. It changes the solution of salts of iron, with the maximum oxid, to a bright red, and those of copper to an emerald green. It does not possess any of the narcotic properties of opium, in this respect differing from morphia.

It is supposed by Serteurner to exist in opium, in union with morphia.

Kinic Acid.

When the solution of Peruvian bark in cold water is concentrated by evaporation, crystals are gradually deposited, which consist of lime and a peculiar acid called *kinic*, from which, when dissolved, the lime can

be precipitated by oxalic acid. The solution after filtration crystallizes.

Kinic acid is distinguished from others, by forming a soluble salt with lime, and in not precipitating lead from its solutions.

Besides the acids described, others have been mentioned by different chemists. Many of these, however, have now been found to be merely the common acids disguised by the presence of some vegetable principle; but others still maintain their title to be considered distinct acids, though their properties have not been minutely investigated. Such are *igasuric acid*, discovered by Pelletier and Caventou, in *St Ignatius's bean*, (An. de Ch. et de Ph. viii.); *ellagic acid*, existing in *nut-galls*, described by Braconnot, (same work, ix.); *boletic acid*, discovered by the same chemist in the *boletus pseudo-ignarius*, (An. of Ph. ii.) and *moroxylic acid*, found in the fruit of the *sorbus alba*, (Nich. Journ. viii.)

SECTION IV.

VEGETABLE ALKALIES.

Of late several vegetable substances employed in medicine, have been found to contain peculiar principles, in which the active qualities reside, and which, from their neutralizing acids, and forming with them soluble salts, bear a strong resemblance to the alkalies.

They exist in the different plants from which they have been procured, in a state of combination with an acid; and as their salts are soluble, and are easily decomposed, the process followed in procuring them, consists merely in the removal of this acid, and also of the other vegetable substances with which it may be mixed. The method in general practised for decomposing the salts, is by the addition of an alkali or earth, which uniting with the acid, precipitates the vegetable alkali. But as it is not pure, it may be dissolved by warm alcohol, and while hot, filtered through animal charcoal, after which it is deposited when the solution cools; or the precipitate may be dissolved by a weak acid, as acetic, in this state filtered through charcoal, and then precipitated by another base, as ammonia.

The vegetable alkalies are sparingly soluble in water, and in cold alcohol; but the latter when warm easily dissolves them, and of course deposits them when its temperature falls. They are destructible by heat, and what is very remarkable, they all yield ammonia by their decom-

position, shewing that in addition to the usual ingredients, they must also contain nitrogen. They have a weak affinity for acids, and of course their salts, most of which are very soluble, are easily decomposed by other bases.

The vegetable alkalies are

Morphia,	Strychnia,	Delphia,
Cinchonia,	Brucia,	Atropia,
Quinia,	Picrotoxia,	Hyoscyama,
		Emetia.

Morphia.

Opium, besides several of the common vegetable principles, contains a peculiar substance, in union with meconic acid, in which the narcotic quality resides.

Derosne first drew the attention of chemists to it, (An. de Ch. xlv.) and concluded that it was the active principle of opium. He found that it possessed alkaline properties, but which he ascribed to the potassa employed in its preparation, having been procured by precipitation by that substance from infusion of opium. Seguin seems to have procured it in 1804, an account of which he read to the French Institute, but it was not published till 1814, (An. de Ch. et de Ph.) Lastly, Serteurner, about the same time, gave an account of a substance in which he considered the peculiar properties of opium resided, (Tromsdorff's Journal, xiv.) These experiments were entirely overlooked by Chemists, till Serteurner in 1817 again drew their attention to the subject, (An. de Ch. et de Ph. v.) He then gave an account of a substance which he called morphia, considering it the active principle of opium, and clearly established its claims to be ranked among the class of alkalies. Though he states that the substance procured by Derosne was altogether different, considering it a compound of the acid of opium, (meconic acid,) yet in this he is evidently wrong. Derosne's precipitate was morphia in its impure state, and thrown down by the potassa, having combined

with the meconic acid, with which it was in union. We are to consider Derosne, therefore, as the discoverer of morphia, but Serteurner certainly first obtained it pure; and, having shewed it to be alkaline, has the merit of having paved the way for the subsequent discoveries of chemists with respect to vegetable alkalies.

Different methods have been recommended for procuring it. The process followed by Serteurner consists in macerating opium with acetic acid, filtering, and precipitating by ammonia. The processes, however, by which it is obtained in greatest quantity, and in the greatest state of purity, are those of Robiquet and of Thomson. The following is that of Robiquet, (An. de Ch. et de Ph. v.) Boil a concentrated solution of a pound of opium with 100 grains of magnesia, during a quarter of an hour; filter, and wash the precipitate, which consists of morphia, narcotin, meconate of magnesia, and colouring matter, first with cold water, and then with warm diluted alcohol, to dissolve the narcotin and colouring substance. Then boil the insoluble residue in alcohol, which will take up the morphia, and deposit it in slender crystals, as its temperature falls. If not colourless, it may be purified by repeated solution in alcohol, and crystallization.

The process of Thomson, (An. of Ph. xv.) consists in adding to a concentrated watery solution of opium, aqua ammoniæ, as long as it throws down a precipitate, which consists of morphia and colouring matter. After filtration wash it with alcohol, and dissolve it in acetic acid; and by repeated agitation with ivory blacking, and filtration, the morphia can be precipitated by ammonia. If not colourless, it must be dissolved in alcohol, and purified by crystallization.

The precipitate thrown down by ammonia may, as recommended by Hottot, (Quarterly Journal, xvii.) be dissolved at once in warm alcohol, and the solution decolorized by charcoal, by which crystals of morphia may also be obtained.

According to Brande, a pound of opium will yield

about 500 grains of morphia; but it is doubtful if, by any of the processes followed, the whole of the morphia is obtained; indeed, Robiquet found that the fluid from which it had been precipitated, still contained a considerable quantity. Mr Henry states that most is procured when lime is employed to precipitate it from the infusion, (Bull. Univ. b. xi.)

Morphia is obtained in four-sided rectangular prisms, having a pearly lustre. It is sparingly soluble in water, but easily dissolved by warm alcohol, which deposits the greater part of it when the temperature falls. The solutions have an intensely bitter taste, and have the same effect as the alkalies on vegetable colours.

Morphia, when heated slightly, is fused, and, on cooling, crystallizes. It is decomposed by strong nitric acid, being converted to oxalic; but when diluted, it unites with it; and it combines also with other acids, and forms neutral salts. It decomposes some of the metallic compounds, uniting with their acid, and precipitating the oxid.

Morphia has been analysed in the usual way, but very different statements have been given of its composition. The following are the results of the analyses by Brande, (Quarterly Journal, xvi.) Dumas, and Pelletier, (An. de Ch. et de Ph. xxiv.), Bussy, (An. of Ph. N. S. vi.) Thomson, (An. of Ph. xv.);

	Brande.	Dumas, Pelletier.	Bussy.	Thomson.
carbon,	72.	72.02	69.0	44.72
oxigen,	17.	14.84	20.	49.69
hydrogen,	5.5	7.01	6.5	5.59
nitrogen,	5.5	5.53	4.5	0.0

The result of Thomson, so completely at variance with all the others, not only with respect to the proportion of the ingredients, but also to the absence of nitrogen, would lead us to suppose, either that the morphia has been impure, or that some mistake has been committed in the analysis.

It has been proved, by satisfactory trials, that morphia is the narcotic principle of opium. Serteurner found that a half grain produced headache, and encrease of the

muscular energy. An additional half grain induced stupor, vertigo, and nausea; and when the dose was encreased to 1½, the symptoms became so alarming as to make him have recourse to means to counteract them. When administered cautiously, it produces the beneficial effects of opium, without any of those unpleasant feelings sometimes attendant on its administration; and it does not seem to be deprived of its properties by union with an acid. Though alarming symptoms follow the use of a small dose of morphia, it has been found that a much greater quantity may be swallowed, provided it is not in solution, the powder acting very slowly on the system. Hence the means of counteracting an over-dose of it, or of opium, by the administration of alkaline carbonates, by which it is precipitated *.

Cinchonia.

The febrifuge qualities of Peruvian bark have been ascribed, at different times, to different substances supposed to exist in it. Dr Duncan was the first who threw out the conjecture, (Ed. Dispens. edition 1811,) that bark contains a peculiar principle, which he inferred from finding that re-agents produced changes not to be accounted for by the qualities of other vegetable bodies. To this substance he gave the name of *cinchonin*. This opinion of Duncan was afterwards confirmed by the ex-

* From what has been said of the properties of morphia, it must be evident to any one who will read the paper of Derosne, that the substance which he obtained was the same. He procured a crystalline matter from the watery infusion of opium, by spontaneous deposition, and also by the addition of carbonate of potass, and which he was inclined to consider one and the same. Of this there seem some doubts, but with respect to the last there can be none, that it was morphia. It was, according to him, soluble in boiling alcohol, being precipitated as the temperature fell. Its solution changed violets to green. It combined with acids, and formed soluble compounds. Supposing that the effect on the violets might depend on the presence of potassa, he tried to wash this off, but still the substance changed the colour. Lastly, a minute quantity given to dogs, produced the violent symptoms of an over-dose of opium. Serteurner has, therefore, merely confirmed the experiments of Derosne; and, in addition, has proved the alkaline property of morphia.

periments of Dr Gomez of Lisbon, who succeeded in procuring cinchonin from bark, (Lisbon Phil. Trans.); and Pelletier and Caventou having afterwards proved that it belongs to the class of vegetable alkalies, it has now received the name of *cinchonia*.

The process followed in procuring it, is nearly the same as that by which morphia is obtained. Perhaps the easiest is that described by Brande, (Manual of Pharm.) Boil a pound of pale bark, *(cinchona condaminea,)* bruised, in a gallon of water mixed with three drachms of sulphuric acid, and after pouring off the decoction, repeat the process till the whole of the soluble matter is extracted. Mix the fluids, and add slaked lime in sufficient quantity to neutralize the acid employed, and a precipitate of cinchonia and of sulphate of lime falls, which, when boiled in alcohol, yields cinchonia by evaporation of the solution.

Cinchonia is a white semi-crystalline substance, sparingly soluble in water, but easily dissolved by warm alcohol, which, when it cools, deposits it. It has an extremely bitter taste, and its solutions change vegetable colours to green. When heated, it is volatilized, and by the application of a proper temperature, is decomposed, and yields along with the usual ingredients ammonia; so that it must contain nitrogen. The analyses by Brande, and by Pelletier and Dumas, by no means agree; so that, as yet, we are quite undecided with respect to its composition. The following are the results:

	Brande.	Dumas.
carbon,	79.30	76.97
oxigen,	0.0	7.79
hydrogen,	7.17	6.22
nitrogen,	13.72	9.02

Cinchonia unites with acids, and forms, in general, neutral salts. The sulphate, muriate, nitrate, and acetate, are soluble; oxalate, tartrate, and gallate, are insoluble in cold water. Hence the infusion of bark is precipitated both by gelatin and by galls, the former removing the tannin always existing in it, and the latter yielding gallic acid to deposit the cinchonia.

That cinchonia possesses the febrifuge quality of bark, has been proved by the experiments of Double and others, (Ed. Dispens.)

Quinia.

During their analysis of bark, Pelletier and Caventou discovered in that variety, commonly called yellow bark, *(cinchona cordifolia,)* another alkaline principle, to which they have given the name of *quinin* or *quinia*. It is obtained by a process similar to that by which cinchonia is procured. It is a white pulverulent substance, sparingly soluble in water, but dissolved by warm alcohol, from which, however, it is not deposited in crystals, as is the case with morphia and cinchonia.

It has been analysed by Brande and by Pelletier, but the results are discordant; they are,

	Brande.	Pelletier.
carbon,	73.80	75.02
oxigen,	5.55	10.43
hydrogen,	7.65	6.66
nitrogen,	13.00	8.05

Quinia unites with acids, and forms salts, the most important of which is the sulphate. It is soluble in water, and crystallizes. It is now much employed in medicine, being found to answer all the purposes of bark; and as a small dose is necessary, it does not produce the unpleasant effects of the bark powder or infusion. Eight grains are considered equal to an ounce of the powder.

Oxalate, tartrate, and gallate of quinia, are insoluble.

The experiments of Pelletier and Caventou have shewn, that the pale bark contains only cinchonia, the yellow bark quinia, but the *red bark (cinchona oblongifolia,)* has both, and in all they are in union with kinic acid. Other kinds, however, do not contain either, and as the febrifuge quality depends on the presence of one or other, it is of importance to be able to know, by an easy experiment, whether any of them exists in a bark. The simplest method of effecting this is by the addition of infusion of galls, which, from the gallic acid it contains, will

yield a precipitate, provided one of the alkalies is present. If there is no precipitation, neither is present, and the bark will be quite inert.

Strychnia.

Strychnia was discovered by Pelletier and Caventou, in the fruit of the *strychnos nux vomica*, and of the *strychnos Ignatia*, or St Ignatius's bean. It was afterwards detected in the poison of the *Upas tree*, (An. de Ch. et de Ph. x.—xxvi.)

It is procured by the same process as that followed by Robiquet, in the preparation of morphia, by which it is obtained in four-sided prisms. It is very sparingly soluble, requiring upwards of 6000 of cold, and 2500 of hot water to dissolve it. The cold solution, though diluted with 100 parts of water, has an intensely bitter taste. It is one of the most virulent poisons with which we are acquainted; half a grain, when blown into the mouth of a rabbit, produced lock jaw, and proved fatal in five minutes.

It unites with acids, and forms salts, most of which are soluble.

In the different species of strychnos it exists in union with igasuric acid.

Its composition, according to Pelletier and Dumas, is,

carbon,	78.22
oxigen,	6.33
hydrogen,	6.54
nitrogen,	8.92

Brucia.

Brucia was discovered by the same chemists in the *Brucia Antidysenterica*, and in minute quantity in St Ignatius's bean. It was obtained by digestion in ether, and afterwards in alcohol, evaporating the alcoholic solution to dryness, and dissolving the residue in water. On the addition of oxalate of ammonia, oxalate of brucia

was deposited, from which the oxalic acid was abstracted by lime, (An. of Ph. xv.)

Brucia is crystallizable. It is sparingly soluble in water, the solution having a less bitter taste than that of strychnia; it is also poisonous, but not nearly so much so as strychnia. It is decomposed by heat, affording the usual products. It unites with acids, and forms salts.

According to Pelletier, it is composed of,

carbon,	75.04
oxigen,	11.21
hydrogen,	6.52
azote,	7.22

Picrotoxia.

The berries of the *cocculus indicus (menispermum cocculus)* have been found, by Boullay, to contain a peculiar principle, to which the name of *picrotoxia* has been given. It may be procured by the addition of ammonia to the infusion of the berries, washing the precipitate with cold water, and dissolving it in alcohol, from the solution in which it is procured by evaporation.

It is a white crystalline substance, soluble in 25 of warm water, and from which the greater part is deposited as the temperature falls. It is also soluble in warm alcohol. Nitric acid converts it to oxalic, but the other acids form with it neutral salts; from the solution of which, alkalies and their carbonates precipitate it, (An. of Ph. xvi.)

Delphia.

Delphia was discovered, by Lassaigne and Feneulle, in the seeds of the *delphinum staphysagria*, in which it exists combined with oxalic acid. It is obtained by the process of Robiquet, of precipitation by magnesia, and solution by alcohol.

It is a white crystalline substance, apparently insoluble in water, but dissolved by alcohol. The solution has an acrid taste, and changes blues to green.

Delphia unites with acids, and forms neutral salts, (An. of Ph. xvi.)

Atropia.

Atropia was discovered, by Mr Brande, in the leaves of the *atropa belladonna*, and may be extracted from it in the usual way by magnesia. It is a white tasteless powder, very sparingly soluble in water, but dissolved by warm alcohol, from which it is deposited as it cools. It unites with acids, and forms salts, all of which, when swallowed even in minute quantity, produce the unpleasant effects of belladonna itself, headache, diminished circulation, and dilation of the pupils, (An. of Ph. N. S. i.)

Veratria.

Veratria was discovered in the seeds of the *veratrum sabadilla*, in the roots of the *veratrum album*, and of the *colchicum autumnale*, by Pelletier and Caventou, and from which it is procured in the usual way, (An. de Ch. et de Ph. xiv.)

It is a white pulverulent substance, destitute of smell, but when drawn into the nostrils, inducing severe sneezing. It has an acrid taste, and when swallowed even in very minute quantity, excites painful sickness and vomiting. It is sparingly soluble in water, but easily dissolved by warm alcohol, the solution changing blues to green. It unites with acids, and forms salts which have in general an excess of acid. According to Pelletier and Dumas, it consists of

carbon,	66.75
oxigen,	19.60
hydrogen,	8.54
nitrogen,	5.04

Emetia.

Pelletier and Dumas have shewn, that the emetic pro-

perty of ipecacuanha, resides in a peculiar principle to which they have given the name of *emetia*. It is obtained from the decoction of the root in the usual way, by precipitation, by means of magnesia, and solution in warm alcohol.

Emetia is a white powder, sparingly soluble in cold, but easily dissolved by warm water. It is soluble also in alcohol, but ether does not act on it. It fuses at 122.

It enters into union with acids, and forms salts, but which have not yet been obtained crystallized. (An. of Ph. xi.)

According to the above-mentioned chemists, it is composed of

carbon,	64.57
oxigen,	22.95
hydrogen,	7.77
nitrogen,	4.00

Besides the vegetable alkalies already described, others have also been mentioned, as *hyosciama*, existing in the hyosciamus niger; *solania*, in the solanum dulcamara. There is every reason to believe, also, that the active qualities of the *digitalis purpurea*, *conium maculatum*, and some others, reside in alkaline bases.

PART IV.

ANIMAL CHEMISTRY.

SECTION I.

Animal, like vegetable matter, is composed of few elementary ingredients; indeed, with the addition of nitrogen, they are the same, but this is sufficient to give them properties by which they are easily distinguished. The presence of nitrogen, for instance, causes them quickly to run into putrefaction, and in general without passing through the vinous or acetous stages, and during the decomposition ammonia is always evolved.

The chemical history of the animal kingdom, may be divided into two parts.

1*st*, Of the proximate principles.

2*d*, Of the different solids and fluids, which, with a few saline ingredients, are made up of the substances to be treated of in the first section.

Before, however, proceeding to the description of them, a great deal of useless repetition will be saved, by a short account of the general properties of animal matter.

When animal matter, as flesh, is subjected to distillation, it affords a watery fluid, an empyreumatic oil of various degrees of consistence, liquid, and concrete, carbonate of ammonia, with acetic acid, and carburetted hydrogen, having a disagreeable smell. The residue is carbon, with carbonates of potass and soda, and phosphate of lime, with occasionally iron and manganese.

Water, when aided by heat, dissolves a considerable

portion of animal matter, and the solution, on cooling, if not too much diluted, forms a gelatinous mass.

The acids act with great ease. When, for instance, nitric acid is poured on flesh, there is a decomposition of both, accompanied with the evolution of nitrogen, nitric oxid, and carbonic acid; and if heat be applied, hydro-cyanic acid is disengaged, and a yellowish coloured solution is formed, containing oxalic and malic acids. If the nitric acid employed, be diluted with about 2 parts of water, and a slight heat applied, the action is more moderate, the flesh becomes yellow, and nitrogen gas is evolved, and may, by carrying on the action in a retort, be collected in a jar on a water trough.

When flesh is put into sulphuric acid, the colour is at first destroyed, but it afterwards becomes dark brown, and at last a rich red solution is formed.

The alkalies act on animal matter. When, for instance, flesh is put into solution of caustic potass, a saponaceous fluid is produced, and a fetid ammoniacal odour is emitted.

Animal matter is decomposed by some of the compound salts. The action with chlorate of potass is interesting, as constituting the method of analysis followed by Gay Lussac and Thenard, in ascertaining the proportion of the ingredients of its different principles, the decomposition being effected in the same way as with vegetable bodies.

Animal, like vegetable matter, undergoes spontaneous changes, but it seldom passes through all the states of fermentation; the most common is putrefaction, which very quickly commences, provided it is exposed to a proper temperature and moisture. The nearer the former is to 90, it takes place more speedily; if it fall below 32, it ceases entirely. Moisture is also necessary, and the more freely air is admitted, it is the more rapid. The first effects are, a change of colour and consistence. The matter, say flesh, becomes paler and softer, and emits a disagreeable odour, accompanied with the evolution of aeriform fluids, which differ according

to the substance undergoing the change. They are principally carbonic acid, carburetted and sulphuretted hydrogen, ammonia, and occasionally also a little phosphuretted hydrogen. After the disengagement has continued for some time, the matter ceases to emit the offensive odour, and it becomes a dry friable mass, having a greasy feel. It contains ammonia, carbon, oily matter, and the other fixed principles of the animal kingdom.

When the substance is buried, the putrefaction goes on more slowly, particularly if the earth in which it is deposited is dry, as in this case the moisture is absorbed, by which putrefaction is retarded.

When the action of the air is completely excluded, as when a number of dead bodies are heaped together, the results are different from those already mentioned. The changes which occur under these circumstances were first noticed in Paris, in 1786. On opening the pits of a burial-ground, in which about 1000 dead bodies had been buried, it was found that almost the whole was converted to a saponaceous substance, having a greasy feel, which melted like tallow, and, on cooling, became crystalline. When exposed to a high temperature, it burned like wax. When put into nitric acid, a fatty matter was separated; and, with the fixed alkalies, it gave out the odour of ammonia. The fatty substance produced by acid, had all the appearance of spermaceti, being soluble in alcohol, and burning with a bright white flame. According to Chevreuil, it contained margaric acid.

A substance of a similar nature may be formed by causing animal matter to undergo putrefaction more quickly, as by exposing it to the action of a stream of water, in which case three or four weeks are sufficient.

Various means are resorted to for retarding animal putrefaction; a reduction of temperature is by far the most efficacious. Meat, when put into snow or ice, may be kept almost any time, and hence the common practice of sending fish to a distance, packed in it. In cold

countries, also, a store of provisions is laid up, surrounded by snow, in which state it remains till required for use. Depriving animal matter of its moisture, is another mode of preventing putrefaction. We find, accordingly, that dried fish may be kept for a long time. In some countries, it is also the custom to cut flesh into thin slices, and dry it gradually, by which it may be preserved till provisions cannot be otherwise procured.

There are many substances that retard putrefaction, some of which, it is supposed, act merely by absorbing the moisture of the animal matter. The most powerful of these is common salt, which is used in great quantity for preserving butcher's meat, fish, butter, and many other articles. Of late pyroligneous acid has been highly recommended for this purpose. It is even said that it will render sweet, animal matter that has become putrid. In using it, the meat is merely dipped in, and almost instantly removed. Should it have become putrid, it may be left in for a few minutes.

Other means have also been practised for preventing putrefaction. The complete exclusion of air, it is well known, retards it; hence the custom of rubbing eggs with salt butter, and of keeping them in lime water. Flesh is also sometimes preserved in this way; for which purpose it is put into a cask, afterwards made as air tight as possible. It has been found also, that by boiling meat for some time, and then putting it into barrels, it may be kept long without putrefying; and hence a practice often resorted to in long voyages.

From what has now been said, it is evident that the elementary ingredients of the animal kingdom, are carbon, oxigen, hydrogen, and nitrogen; but, in addition to these, there are also saline, earthy, and metallic matter, as sulphates, phosphates, and muriates of potass, soda, lime, and iron.

Guy Lussac and Thenard, from their researches into the intimate nature of animal bodies, have concluded that they contain more carbon than exists in vegetables, and that the hydrogen is always in greater proportion than will

form water with the oxigen; but as, in addition to the elements of vegetables, there is also nitrogen, it has been found that the greater the excess of hydrogen, the more nitrogen they contain, so that ammonia is one of the products of their decomposition. When the hydrogen is just in such proportion as to convert the oxigen into water, and the nitrogen to ammonia, they observed that the animal matter was neither acid nor oleaginous, and hence the division suggested by them, into,

1*st*, Animal matter, not acid or oleaginous.
2*d*, Animal acids.
3*d*, Animal oils.

To the first class belongs the greater number of those bodies strictly called Animal Principles.

SECTION II.

ANIMAL PRINCIPLES.

The animal principles may be divided into two classes.

1*st*, Those that occur dispersed throughout the body. They are gelatin, albumen, fibrin, mucus, osmazome, and oils.

2*d*, Those that are found in particular solids or fluids, and in these only. They are picromel, cholesterine, and ambergris, existing in bile; sugar of milk, butyrin, and casein, in milk; urea, and uric acid, in urine.

The first class only will be described in this section. The second will be considered along with the substances to which they are peculiar.

Gelatin.

When an animal substance, particularly skin or any cartilaginous part, after being well washed, is boiled in water for a considerable time, a semi-transparent solution is formed, which, when evaporated and allowed to cool, becomes a tremulous mass called *jelly*. If this be again heated, it is melted, and, on continuing the heat, the whole of the water is evaporated, and a hard solid matter remains, which is *gelatin*.

Though gelatin may, and frequently is, procured by the process mentioned, yet it is not pure. The source from which it is obtained in the greatest state of purity, is *isinglass*; and from it its properties have been in general described.

Gelatin is a hard brittle substance, inodorous, insipid, and colourless. When exposed to heat, it crisps, soon becomes black, and is completely charred. When heated in close vessels, it affords a watery fluid containing ammonia, and a fetid empyreumatic oil.

It has been analyzed by Gay Lussac and Thenard, by burning it with chlorate of potass. It is, according to them, composed of

carbon,	47.881,	probably 15 atoms,
oxigen,	27.207,	—— 6 atoms,
hydrogen,	7.914	—— 14 atoms,
nitrogen,	16.998	—— 2 atoms.

When gelatin is put into cold water, it softens and swells, but is not dissolved. When the fluid is boiled, a solution is formed, the consistence of which depends on the quantity, and which, when evaporated, yields the principle unchanged in its properties. According to Bostock, when it contains 1-100th part of gelatin, it will gelatinize on cooling; but when there is only about 1-150th, it does not become concrete.

The strong solution, and which has congealed on cooling, may be kept almost any time without undergoing a change; but the weak one becomes sour, and emits an offensive odour.

When chlorine gas is passed through the solution, a white flocculent matter is separated, which, when exposed to air, becomes a dry powder, insoluble in water, but soluble in warm nitric acid. It consists apparently of gelatin in union with muriatic acid and chlorine. When exposed to heat, chlorine gas is emitted, and with alkalies it forms muriates.

The acids, though diluted, act on gelatin. Nitric acid decomposes it; nitric oxid is disengaged, and a solution is formed, which contains oxalic and malic acids, with an oily fluid floating on its surface.

Muriatic and acetic acid dissolve it without decomposition.

The action with sulphuric acid is peculiar, a solution being formed, from which saccharine matter can be ob-

tained, as at first pointed out by Braconnot, (An. de Ch. et Ph. xiii.) For this purpose, 12 parts of gelatin are kept in twice their weight of acid for twenty-four hours, and then mixed with about 6 times their weight of water, the mixture boiled, and saturated with chalk. After filtration and evaporation, crystals having a sweetish taste are procured, but which differ from common sugar, in being more easily crystallized, in not fermenting with yeast, and in yielding ammonia by their destructive distillation.

Gelatin is dissolved by alkaline solutions. The compound formed has none of the properties of soap, and is not decomposed by acids; by which it is distinguished from other animal principles.

The earths do not produce any change on gelatin. The metallic oxids and their salts are very little affected by it. The solution of nitrate of silver, and nitro-muriate of tin, become slightly opake. Sub-acetate of lead is not altered by it.

Gelatin is not dissolved by alcohol; accordingly, when its concentrated watery solution is mixed with it, a precipitate instantly appears.

The most important action of gelatin is with tannin. When an infusion of nut-galls, or of any astringent matter, is added to solution of isinglass, a whitish precipitate is formed. If strong infusion be employed, a tough elastic substance is thrown down, which, when dry, becomes hard and easily broken. The precipitate is a compound of gelatin with the astringent principle, a *tannuret of gelatin*, and it was at one time supposed that this might serve as a means, not only of indicating the presence, but of ascertaining the quantity of the animal matter in the fluid. Other substances are, however, precipitated by tannin, such as albumen. Of course, before we can employ it as a test of gelatin, it is necessary to remove these, which can be easily done by the proper reagents. Though tan may, with these precautions, be used as a test, it cannot be employed to indicate the quantity of gelatin, the composition of the precipitate

varying apparently according to the strength of the solutions.

If, instead of mixing the fluids, the gelatin in any animal solid be kept in an infusion of tan, the union is also effected, though more slowly. Hence the art of tanning, which is merely uniting astringent matter with the gelatinous part of skins, by which they are gradually converted to leather, a substance insoluble in water, and not liable to undergo decay. Other methods are also practised in the preparation of certain kinds, the description of which, though not strictly connected with the action of tan, may be introduced in this place.

For converting skins into leather, different processes are followed, according to their nature, and the kind of leather required; as *tanning*, or causing them to unite with astringent vegetable matter; *tawing*, or soaking them in alum and other salts, with some animal substance; and *currying*, or besmearing them with oil to render the leather soft, and impervious to water. These processes are often performed on the same skin, by which the leather is fitted for more purposes. The thick hides of which the soles of shoes are made, are merely tanned, while the white kid glove leather is tawed. That for the upper leather of boots and shoes, is both tanned and curried, and the fine Turkey leather is first tawed, and afterwards tanned.

When the skin is to be tanned, after being freed from impurities, it is put into a pit with lime water, for some days, by which the hair is loosened, and is easily removed, but as the lime makes it hard, it is necessary to soften it; for which purpose, it is put into the *mastering* pit, containing water and dung, chiefly of pigeons or fowls, where it continues for some days, the time depending on its thickness.

When the skins are very thick, they are sometimes submitted to another process; a number of them are heaped together in a warm place, so as to cause a slight putrefaction, after which the hair is removed, in general without immersing them in the lime pit, as this would

harden them too much, and render the leather liable to crack. They are then put into a vat, containing a sour fluid, generally prepared by allowing rye or barley to ferment in it, occasionally much diluted oil of vitriol, by which they are softened, and their pores opened, so that they can more easily imbibe the tan liquor.

The next stage of the process is the tanning, which consists merely in soaking the hide in a solution of an astringent vegetable, and making this unite with the gelatin, by which it is rendered no longer liable to undergo putrefaction, insoluble in water, and in a great measure impervious to it. The astringent substance usually employed is oak bark, procured from the trees which are cut in spring, when the sap has risen in them. After being reduced to coarse powder, it is put into pits with water, by which a solution of the astringent matter is procured, called an *ooze*. In this the hides are immersed for several weeks, being frequently turned, to expose the whole to the infusion, and allow it to penetrate them. From this pit they are placed in others, the liquor being successively stronger, till it is completely saturated. Should the hides be very thick, the last into which they are put contains some of the powder of the bark in alternate layers with them, by which, as the infusion becomes weaker by the substance combining with the gelatin, more of it is taken up, and it is thus always kept of proper strength. In this way they are allowed to remain, till the whole is converted to leather; the time required, depending on their thickness. Calves' skins take from two to four months, and the thick sole leather hides, from fifteen to twenty.

Seguin proposed what seemed to him an improvement in the mode of preparing leather, but which has not been adopted in this country. It consists in making quickly, solutions of the oak bark of different strengths, and passing the hides through them, beginning with the weakest, and ending with the strongest, by which the process is considerably shortened. It is said, however, that the leather thus prepared, is more liable to crack than that manufactured in the usual method.

As oak bark contains a number of other substances, besides the astringent matter, the quality of the leather depends, in a great measure, on the mode in which the infusions are made. One of the ingredients of bark is *extract*, which is soluble, but not so much so as the astringent matter. Skin has the property of absorbing this, by which the leather probably acquires its colour and flexibility; if, therefore, the tan liquor be so made, that it contains little of the extract, the leather prepared may absorb a great deal of the astringent principle, and thus become brittle, and more liable to crack. Hence likely the cause of that manufactured in the French way not being so durable as the other, for, by the method of forming the tanning fluid, much of the astringent and little of the extractive matter is dissolved. Besides, when the process is carried on quickly, the outer part of the skin only is converted into leather, because, this being speedily tanned, prevents the fluid from penetrating any farther.

The great objects to be attended to, then, in tanning, are, to procure from the bark as much of the soluble matter as possible; and could some means be devised by which the skins could be made to imbibe this quickly, and uniformly, a great deal of labour, time, and money, would be saved. On this is founded the patent process of Spilsbury, which consists in forcing in the tan liquor by pressure; but though the tan is thus quickly imbibed, the leather, it is said, is not durable, the skin not being uniformly tanned.

The *tawing* of skins, by which they are also converted into leather, is more speedily accomplished than tanning. The skins subjected to this process, are those of goats, sheep, lamb, and other thin hides, by which *glove leather*, and that usually called *morocco*, are prepared. When the leather is to be white, it is merely subjected to tawing; but when intended to be dyed, it also receives a slight tanning.

Tawing consists in soaking the skins, previously freed of impurities, in a warm solution of alum and common

salt, by which they become thick and tough. They are then, after being washed, put into a vat with bran and water, and allowed to ferment for a short time, so as to remove a great deal of the saline matter, after which they are stretched on frames, and kept in a heated room to dry. By these means, a thin white leather is procured, which is made glossy, by soaking it in water containing the white of eggs, and when dry, smoothing it with a hot iron.

In the process of tawing, it is supposed that the skin imbibes something from the saline matter, probably *alumina*, which, by combining with the gelatin, converts it to leather, in the same way as the astringent matter does in tanning.

When the leather is to be dyed, as in preparing black morocco, after being tawed, it is soaked in an infusion of *shumach* (the shoots of an astringent plant, and of course similar in its nature to oak bark,) and then rubbed over with a solution of green vitriol.

Currying consists in soaking leather in some oily substance, so as to render it more impervious to water, for which purpose, the hides, after being tanned, are besmeared with oil, or oil and tallow.

It is of the utmost consequence for tanners, and others using astringent matter, to be able to judge of the quantity of *tannin* in any article exposed for sale, particularly as it varies so much in different samples, owing, partly to the age of the vegetable, and to adulteration. Different methods have been recommended, but by far the best, is just that followed by tanners, but conducted in such a way as to be quickly finished. It is well known that skins will continue to imbibe the astringent principle for many months; but on a small scale, the whole tan may be removed from an ooze in a few hours. For this purpose, the astringent matter being ground to powder, 1000 grains are to be infused in water at about 100, and after the whole of the tan seems dissolved, the fluid must be strained, and the insoluble matter washed, till the water passes through tasteless. A certain quantity of this, say 1-10th, is to be placed in a

bottle, along with pieces of skin, previously washed with warm water, to dissolve the lime employed in taking off the hair, and to remove the loose gelatin; the skin being dried, and weighed before being put into the bottle. Leaving them there for a few hours, turning them frequently, the whole of the tan will unite with the gelatin, and thus convert the skin into leather, so that, by drying it, and weighing, we find the quantity of tan that existed in the infusion, of course of 100 grains of the astringent matter, (An. of Ph. N. S. xi.)

Gelatin is procured from different parts of the body, these affording different kinds of it, or rather articles containing it, but mixed with other substances. They are *glue*, *isinglass*, and *size*.

Glue is procured by steeping skins, bones, flesh, and the cartilaginous parts of animals in water, the skins particularly of young animals being considered the best. To obtain it, after being soaked in lime water, to remove impurities, they are washed, and afterwards boiled, the scum as it rises being removed. Alum in powder is next added, and the solution is strained, and boiled to the proper consistence, the scum as before being taken off. When sufficiently evaporated, it is poured into moulds, in which it congeals, and is then cut into thin slices, and dried in the air.

Isinglass is the dried sounds of fish, particularly of sturgeons. They are merely washed in cold water, and, after being deprived of their outer covering, and cut into small pieces, are dried by exposure to air.

Size, the substance used by painters, is prepared by boiling in water, pieces of parchment, of skins, and fins of fish, and evaporating the solution to a proper consistence. It differs from glue, in containing fewer foreign ingredients, and in not being so strong.

The use of gelatin in preparing leather, has been already described. It is from the ease with which it is acted on by astringent matter, that it is employed also for clarifying fluids, either with the view of removing foreign impurities floating in them, or to carry off some of the

substance in solution. Hence its use in clarifying coffee, which contains not only an astringent matter in solution, but also undissolved matter floating in it, and for this purpose, a piece of isinglass or fish skin is used.

Albumen.

Albumen may be procured by the maceration of different parts of the animal body in cold water, but by this process it is not pure. The substance that yields it in the greatest state of purity, is the glair of an egg, which, though it contains a few foreign ingredients, as sulphur, is sufficiently pure for exhibiting its properties.

As thus procured, it is a thick fluid with a slight taste, but destitute of smell. When kept for some time, it undergoes putrefaction, but when spread thin on paper and exposed to air, it dries, and may then be preserved without putrefying.

When albumen is subjected to a heat of about 160, it coagulates, and forms a white mass, differing in consistence according to the temperature, or rather to the time the heat has been applied. If long continued, it loses considerably in weight, only about 1-5th of the original matter remaining. The residue does not become fluid, as it regains its original temperature; and it is insoluble in water, shewing evidently that its properties are completely altered. If, however, the albumen be heated cautiously, taking care that the temperature does not reach that necessary for its coagulation, it becomes dry, but may after this be dissolved in water; and hence the method of preparing the substance much used as a *clarifier* of wine and other fluids, (Quart. Journ. xv.)

When the heat to which albumen is subjected is high, it is decomposed, and affords the usual products. According to the French chemists, it is composed of

carbon,	52.883	probably	17 atoms
oxigen,	23.872		6 do.
hydrogen,	7.540		13 do.
nitrogen,	15.705		2 do.

Dr Prout has, however, given a different view of its constitution, (An. of Ph. xiii.) It is, according to him, composed of

carbon,	15	atoms
oxigen,	6	do.
hydrogen,	14	do.
nitrogen,	2	do.

Now, if this be correct, it is of the same composition as gelatin, as noticed by Gay Lussac and Thenard, which would lead us to suspect some error in one of the analyses, or if correct, though the relative proportion of atoms is the same, their number must be different.

Albumen is soluble in cold water, and if the quantity of fluid is not great, it becomes solid on being heated. If the solution is weak, it is rendered only opake; but when largely diluted, it does not undergo any change. According to Bostock, if it contain only 1-1000th part of albumen, it loses its transparency when heated, and hence this affords a very good test of its presence.

If, instead of using cold, we employ warm water, the albumen is instantly coagulated, in the same way as on the application of heat alone.

The stronger acids also coagulate it. Nitric acid first coagulates, and then forms a yellow solution. The action with sulphuric acid is peculiar. When poured into it, it is at first coagulated, but afterwards gradually dissolved, the solution acquiring, particularly on the application of a little heat, a rich red colour. If, however, too much heat be applied, the colour becomes dark brown.

The fixed alkalies gradually dissolve albumen; provided heat is applied, ammonia is disengaged, and a saponaceous compound is formed. If the alkaline fluid is much diluted, the action goes on very gradually.

Albumen is easily affected by some of the alkaline, but particularly by metallic salts. When ferro-cyanate of potass is added to its solution in water, there is an immediate formation of a whitish precipitate, and

hence it has been recommended as a test of this animal principle; but before using it, it is necessary to add a little acetic acid either to the test or to the fluid.

Most of the metallic salts throw down albumen. Green sulphate of iron gives a brown, and the per-sulphate a whitish precipitate. The salts of copper, tin, antimony, silver, gold, and platinum, are also affected by it, but the one that acts most easily is per-muriate of mercury, and which, as it does not precipitate solutions of gelatin or mucus, is employed as a test. According to Bostock, a saturated solution of this salt will detect albumen, though dissolved in 2000 parts of water, by the milkiness which it occasions. Should the fluid be much diluted, it is necessary to heat it before adding the salt, which renders it a still more delicate test; and if it is required to precipitate the whole of the albumen, the heat must be continued for some time.

Albumen is coagulated by alcohol and by ether, though dissolved in water, unless when much diluted.

Different opinions have been entertained with respect to the cause of the coagulation of albumen, either on the application of heat, or by the addition of re-agents; but the only one that appears plausible, is that advanced by Dr Thomson. He conceives that albumen in its natural state is solid, and that fluidity is communicated to it by the presence of alkaline matter, which is always found to exist along with it. On the application of heat, the alkali may combine with the water, or probably a little acid may be generated, and the albumen resume its natural form. The coagulation by acids and by alcohol, is to be accounted for in the same way, both of these removing the alkali. With respect to the changes occasioned by metallic salts, the acid and alkali may unite, while the albumen and oxid are precipitated. This opinion seems confirmed by the experiments of Brande, (Ph. Tr. 1809.) who found that, by subjecting white of eggs to the galvanic influence, a coagulum appeared around the negative wire, where it is well known alkalies are

powerfully attracted, so that, by the removal of that necessary for the fluidity, the albumen became solid.

Albumen is precipitated from its solution by tannin, the colour and consistence of the precipitate depending on the strength of the fluids. Since tannin throws down both gelatin and albumen, it is evident that it cannot be employed as a test of either, without previously removing one of them. This is, however, easily done with the latter, by means of corrosive sublimate, which does not affect the former; so that, should there be reason to suspect the presence of both, the fluid, after being heated, must be mixed with the solution of the metallic salt, and filtered. If, after this, tan throws down a precipitate, it must be gelatin.

Albumen exists in different parts of animals, as cartilage, bones, horns, hoofs, flesh, and the membranous parts. It exists also in considerable quantity in blood, from which it is usually procured when required in the arts.

From the properties which it possesses of being coagulated by heat, it is employed for clarifying fluids, as in the refining of sugar, *(see p.* 161.*)*, and in many other processes. When used for nice purposes, and required in small quantity, white of eggs is employed; but for others, particularly on a large scale, bullocks' blood is used. When either of these is put into a warm fluid, the albumen is coagulated, and entangles impurities; and as the scum rises it is removed, so that the whole of the foreign matter may be separated. Albumen acts in the same way also in clarifying spirituous liquors. When, for instance, glair of egg is added to wine, or to any cordial, the albumen is coagulated by the alcohol, and, entangling the impurities, carries them to the bottom.

Fibrin.

When a piece of flesh has been repeatedly washed to extract the albumen, and boiled to dissolve the gelatin, a tough, fibrous, insoluble substance is left, which is fibrin, but not pure, being mixed with the cellular matter, and

with the coats of the vessels and nerves. Fibrin may, however, be obtained pure from blood, by stirring it with a rough piece of wood, before it has begun to coagulate, by which it adheres to it, and may be freed from any impurities by washing. The polypous matter found in the cavities of the heart, and large vessels, is also pure fibrin, being merely the fibrinous part of the blood, separated either when the person is *in articulo mortis*, or immediately after death.

Fibrin is a tough white elastic substance, destitute of smell. When exposed to air, it becomes dry and hard, but does not undergo any particular change. Even when subjected to air and moisture, it does not seem to be altered, provided it is pure, but when not entirely freed from impurities, it soon runs to putrefaction.

When subjected to a moderate heat, it becomes dry and wrinkled, and if the temperature be high, it melts, and exhales the odour of burning feathers. When heated in close vessels, the usual products are given off. According to the analysis of Gay Lussac and Thenard, who have analysed it in the usual way, it is composed of

		Probably
carbon,	53.360	18 atoms.
oxigen,	19.685	5 do.
hydrogen,	7.021	14 do.
nitrogen,	19.934	3 do.

Fibrin is insoluble in cold water, but when boiled in it for some time, it becomes shrivelled, and seems to have undergone a change, for, on the evaporation of the fluid, a residue is obtained, which is soluble in cold water.

The acids act easily on fibrin. When put into nitric acid, it is dissolved, and nitric oxid and nitrogen are disengaged. When the acid is diluted, the action is moderated, nitrogen alone is set free, and a yellow coloured fluid is formed, on the surface of which a fatty matter is found floating. As the digestion is continued, the fibrin is gradually converted to a yellow substance, which, according to Berzelius, is nitric and malic acid, holding in solution fibrin, but somehow altered.

Sulphuric acid decomposes it, depositing a carbonaceous residue. When the diluted acid is poured on it, a solution of a reddish colour is formed.

Muriatic acid also acts on it, causing the evolution of nitrogen gas, and a hard substance is left, which is insoluble in water. Acetic acid, with the aid of heat, softens fibrin, and forms a tremulous jelly, which, by the addition of water, is decomposed, and nitrogen is evolved. The solution, when mixed with an acid, affords a precipitate, which is a compound of fibrin and the acid employed.

The alkalies dissolve fibrin, but it is at the same time decomposed. When put into aqua potassæ, it becomes soft and swells, and is at last dissolved. The solution is of a greenish colour, and, on the addition of an acid, affords a precipitate, differing, however, from fibrin, in not being soluble in acetic acid.

Alcohol and ether decompose fibrin. When they are kept on it for some time, it is converted to a substance similar to adipocire. The alcoholic fluid, on evaporation, also yields a fatty matter, generated by the decomposition of the animal principle. The adopocirous matter is soluble in alcohol, from which it is precipitated by water.

Fibrin exists in muscular fibre, and in blood, from which it is obtained by the processes described.

It is not put to any use.

Mucus.

The term *mucus* has been generally employed in rather a vague sense; but Dr Bostock has lately applied it to a substance, the properties of which he thinks sufficiently distinct to entitle it to be considered one of the animal principles. It is found nearly pure in saliva, from which it may be procured by evaporation, and re-dissolving the residue in cold water, (Nich. Journal, xi. xiv.)

Mucus is transparent and colourless, has little or no taste, and is soluble in cold water. The solution, when heated to 212, does not coagulate, nor does it gelatinize

on cooling. When evaporated to dryness, it leaves a hard semi-transparent substance, again soluble, so that its properties do not seem to be altered. When, however, the solution is exposed to air, it gradually evaporates, and the residue is not acted on by water.

Mucus, when heated strongly, gives off the usual products, but no analysis has been made of it.

Solution of mucus is not precipitated by muriate of mercury, nor by tannin, in this respect differing from gelatin and albumen. On the contrary, sub-acetate of lead, (Goulard's Extract,) which does not affect either of these principles, throws down a white curdy precipitate from solution of mucus, as may be shewn by adding a drop of it to saliva.

Though Bostock has confined the term mucus to a substance having the properties above enumerated, Fourcroy and Vauquelin (An. de Ch. lxvii.) apply it in general to the mucilaginous fluids lining the different cavities of the body, and which, they say, differ from vegetable gum, in containing nitrogen as one of its ingredients. Berzelius, on the contrary, (Animal Chemistry,) does not admit that there is any one principle entitled to the name of mucus, the fluids found in the different cavities having properties varying according to their situation and use. Bostock's experiments, however, seem sufficient to warrant the conclusion, that what he has described is a distinct animal principle.

Osmazome.

Osmazome may be procured, by subjecting to pressure pieces of flesh, in successive portions of cold water, by which the salts albumen and osmazome are dissolved. By boiling, the albumen is coagulated, and by evaporation to dryness, and treating the residue with cold alcohol, the peculiar principle is taken up.

Osmazome, as procured by the evaporation of the alcoholic fluid, is of a brownish colour, and has the taste and odour of *broth*. When exposed to heat, it gives out the usual products. It is soluble, both in cold water and in

cold alcohol, and from its solution it is precipitated by acetate of lead, and by tannin. It is not, however, coagulated by heat, nor does it gelatinize on cooling. These properties are sufficient to entitle it to be considered a distinct principle. Thenard, who discovered it, gave it the name of osmazome, derived from ὀσμὰ, *smell*, and ζωμὰ, *broth*, being the substance which, according to him, communicates the peculiar odour to that fluid.

The principles now described, are those belonging to the first class, or such as are dispersed throughout the animal frame, or at least are found in different parts of it. The others will be considered when giving the properties of the solids or fluids in which they exist.

Oleaginous Matter.

The oleaginous matter of the animal, is, generally speaking, the same as that obtained from the vegetable kingdom, so that a particular account of its properties is unnecessary.

When solid it is called *fat*, which, when purified, is *tallow*, *suet*, or *lard*. To free it from impurities, it is cut into small pieces, and melted along with a little water, and when fluid, poured through a sieve.

Train oil is obtained principally from the blubber of whales; for which purpose, after being cut into pieces, it is melted by the application of a slight heat, during which water and a coagulum rise to the surface, and are removed.

The sp. gr. of whale oil is about 920; its boiling point 640. When long kept it becomes rancid, but probably owing to the presence of impurities.

Sperm oil is obtained from the oily matter found in the cavity of the cranium of the *physetor macrocephalus*, or *spermaceti* whale, by subjecting it to pressure in linen bags, by which the fluid matter passes through, leaving a white semi-transparent substance, called *spermaceti*. This is much purer than the other animal oils, and is accordingly used for the finer kinds of lamps.

Spermaceti obtained by the above process, resembles wax in many of its properties, being insoluble in water, but dissolved by warm alcohol. The alkalies unite with it, forming a sort of soap.

The properties of *adipocire*, and its formation from animal matter, during putrefaction, have been noticed, (p. 263.)

Animal, like vegetable oils, yields *stearin* and *elain*, and the different acids detected by Chevreuil. The methods of procuring them are similar to those already noticed, (p. 181.)

When hog's lard is distilled, and the product washed with water, the solution, on the addition of acetate of lead, yields a white flaky precipitate, a compound of the oxid, and a peculiar acid, from which it may be freed by sulphuric acid. For this purpose, after being mixed, they are heated in a flask, by which the lead and sulphuric acid are deposited, and the other collecting on the surface, in the form of an oily matter, can be easily removed. Thenard has given it the name of *sebacic acid.* It is soluble in boiling water, has an acid taste, and reddens litmus. It unites with bases, and forms salts, which Thenard calls *sebates.* Though Thenard considers this a peculiar acid, Berzelius is inclined to regard it merely benzoic disguised.

Acids.

The animal acids, besides those in oleaginous matter, already described, are *uric*, existing in urine, *amniotic*, in the liquor amnii, *formic*, obtained from ants; but there are also others produced by the action of re-agents on these, or on other principles, such as *pyrouric*, *purpuric*, *saccholactic*, &c. They will be described along with the substances in which they exist, or from which they are formed, as by this means the account of their properties, and of the methods of procuring them, will be more easily understood.

SECTION III.

OF THE DIFFERENT PARTS OF THE ANIMAL BODY.

The different parts of which the animal body is composed, may be divided into *fluids* and *solids*, in which order it will be most convenient to treat of them.

ANIMAL FLUIDS.

Blood.

The chemical history of blood has long engaged the attention of philosophers; it is but lately, however, that any thing like precise information concerning it has been acquired. Rouelle was the first who published an accurate account of it, since which it has successively been examined by Fourcroy, Deyeux, Parmentier, Brande, and Berzelius. The purposes which it serves in the animal economy, and the changes it occasions, have been investigated by Black, Crawford, Ellis, Edwards, and many others.

Blood varies in different animals. In the lower classes it is colourless, but in the higher orders it is of a red colour, the last of which only has been examined, so that the following detail of its properties refers to it alone.

Blood, when recently drawn, has a thickish consistence, and an unctuous feel. It has a saline taste, and a faint peculiar odour. When taken from a vein, it is of a dark purple colour, but from an artery it is bright red. Its sp. gr. varies from 1030 to 1056.

After it has stood for some time, it undergoes spontaneous changes. A watery vapour arises from it, and it gradually separates into two distinct parts; a thin yellowish fluid called *serum*, and a thick red coagulum, termed *clot*, *cruor*, or *crassamentum*, the proportions of which vary in different individuals, and even in the same at different times. In general, the latter is three times as much as the former, but in some instances it is not more than twice, and in a few rare cases it has been found not to exceed it.

Serum is of a yellowish green colour, having the taste, feel, and peculiar odour of blood. Its sp. gr. varies from 1020 to 1030. It changes vegetable blues to green, owing to the presence of uncombined soda.

When subjected to a temperature of about 160, it coagulates in the same way as white of eggs, and its colour is also changed. If, when in this state, it be cut, a thin fluid exudes from it, commonly called *serosity*, which is merely the watery part, retaining the salts in solution.

According to Dr Marcet, and with whose analysis that of Berzelius very nearly agrees, the component parts of serum are,

water,	900.
albumen,	86.8
muriates of potass and soda,	6.6
sulphate of potass,	0.35
sub-carbonate of soda,	1.65
earthy phosphates,	0.6
muco-extractive matter,	4.
	100.00

The muco-extractive matter is supposed to be impure *lactate (acetate) of soda*.

It was at one time supposed, that besides the ingre-

dients above enumerated, gelatin also existed in serum, but which has, by the most satisfactory experiments, been shewn to be a mistake, and has originated in infusion of tannin throwing down a precipitate from the serosity. Bostock, Marcet, and others, have proved, that after all the albumen is removed, tannin does not occasion precipitation. The removal of the albumen is easily effected by corrosive sublimate, and if, after filtration, tannin be added, it does not produce any change. Serum, it has been supposed, also contains sulphur, because, when kept for some time, it exhales fumes that blacken acetate of lead; but though this proves the presence of sulphur, it is no proof whatever that it exists uncombined.

The *clot* or *crassamentum* is thick like jelly, and when the blood has been taken from a vein, is of a purple colour, but by exposure to air, gradually becomes bright red. When subjected to heat, the usual products are given off.

By the action of water it is resolved into its component parts, a red soluble matter, and a white elastic substance, which is insoluble. To effect the separation, after being cut into small pieces, it is put into a bag, and exposed to a stream of water till it passes off colourless, being at the same time constantly subjected to pressure. The fluid which first comes off is red, and contains the *colouring matter*, along with a little albumen. What remains in the bag is *fibrin*, possessing all the properties of that obtained from other sources. According to Berzelius, they are in the proportion of fibrin and albumen 36, colouring matter 64. That the crassamentum retains albumen is evident; for, on throwing it into boiling water, the fluid instantly becomes turbid.

The *colouring matter*, when viewed through a microscope, is observed to consist of very minute vesicles, apparently of about 1-6000th to 1-4000th of an inch in diameter. They seem to be soluble in water, or rather to contain something that communicates to it their peculiar colour, the globule itself remaining entire. The

solution changes vegetable blues to green, and becomes muddy on boiling, from the presence of albumen. They are also soluble in acids, alkalies, and in alcohol. When subjected to heat, the animal matter is destroyed, and there remains a residue, consisting, according to Berzelius, of

oxid of iron,	50.
sub-phosphate of iron,	7.5
phosphate of lime,	6.
lime,	20.
carbonic acid and loss,	16.5
	100.0

With respect to the nature of the colouring matter, it was at first supposed by Fourcroy and Vauquelin, that it depended on the presence of iron, probably in union with phosphoric acid. They found, that when the residue of the incineration was digested in nitric acid, part of it was dissolved, part continued of a red colour. On the addition of ammonia to the solution, a white precipitate fell, which, when mixed with potassa, became dark red, and on the addition of lime water, gave a deposit of phosphate of lime. They therefore imagined, that a compound similar to the white precipitate, and which is sub-phosphate of iron, exists in the blood dissolved by an alkali, and that in this state it gives the red colour to the albuminous matter. In farther confirmation of this opinion, they state, that when sub-phosphate of iron was dissolved in serum, it made it red, (System of Chem. Knowledge, ix.)

Though these experiments prove that iron exists in considerable quantity in the colouring matter, yet the conclusions are not borne out by the experiment of others. Berzelius, (Med. Ch. Tr. iii.) though he detected iron in it, did not succeed in obtaining a red coloured substance; by dissolving the sub-phosphate in serum, indeed, according to him, it is dissolved with great difficulty. He was unable also, by the usual re-agents, to indicate the presence of iron, except in very minute quantity, so long as the animal matter was not destroyed, but after the in-

cineration, it was easily detected; from which he infers, that the sub-phosphate mentioned by the French chemists must be produced during the process.

Brande (Ph. Tr. 1812,) has advanced an opposite opinion with respect to the colouring matter. He supposes it to be an animal substance, of a peculiar nature, acting in a similar manner to the other colouring principles of organic bodies, and in which he could not detect more iron than is usually met with in animal products in general. To procure it pure, as he conceived, venous blood was stirred during coagulation, by which the fibrin was removed, and the serum holding it in suspension, when kept at rest, deposited it in its concentrated state.

As thus obtained, it was soluble in cold water, the solution acquiring a red colour; but when heated to about 200, the colour disappeared, leaving a pale brown tint, and the fluid became muddy, from the deposit of insoluble matter, for, on filtration, a transparent colourless liquid passed through.

The stronger acids, as sulphuric and muriatic, and also some of the vegetable ones, as acetic, oxalic, citric, and tartaric, according to him, dissolve the colouring matter, and afford a red solution. Nitric acid, however, changes it to brown. It is soluble also in alkalies, and in their carbonates, and without having its appearance altered.

The watery solution is affected by some of the reagents that are usually employed to change the appearance of common colouring matter. Thus the salts of tin and of mercury, throw down red coloured precipitates, the latter acting as a powerful mordant, so that cloth previously soaked in it, and then in the solution of the colouring principle, was dyed permanently a beautiful red.

These experiments, according to Brande, are sufficient to overturn the opinion, that phosphate of iron, or indeed that any of the compounds of that metal, is the cause of the red colour, and they seem, he asserts, to warrant the conclusion, that it is entirely of an animal nature.

In opposition to these experiments, however, Engelhart (Ed. Med. and Surg. Journ. January 1827,) asserts, that he has succeeded in detecting iron in the red particles, and thus, contrary to the position of Berzelius, has proved, as he supposes, that this metal, in some particular state of combination, is really concerned in the production of the colour. He procured the colouring matter pure, by mixing the solution of the particles obtained in the usual way, with a considerable quantity of water, and heating it, by which the colouring principle was coagulated, but owing to the great state of dilution, there was no coagulation of the albuminous matter with which it was mixed.

As thus obtained, the insoluble substance supposed to be the pure colouring matter, was brown, but when dried by the application of a slight heat, became red. It was soluble in alkalies, acquiring the colour of blood. On transmitting a stream of chlorine through the solution of the red particles, a white flocculent matter was deposited, and in the fluid after filtration, which was transparent and colourless, iron was indicated by the usual re-agents, though it could not be previously detected, the presence of animal matter apparently preventing the action of the tests; and thus he accounts for the failure in the attempts of Berzelius to discover it. Though Engelhart has thus succeeded in ascertaining the presence of iron in the solution of the colouring matter, his experiments do not go to prove, in what state of combination it exists, nor how it acts on the other substances, so as to produce the red colour.

This opinion of Engelhart, agrees in some respects with that of Fourcroy and Vauquelin, and it accords with that of Prevost and Dumas, who, in an elaborate paper in the An. de Ch. et de Ph. xxiii., state that the colouring matter is composed of peroxid of iron, and an animal substance, probably albumen.

To obtain *fibrin* pure from the clot, it is cut into pieces, and placed between plies of bibulous paper, which when they have become saturated with fluid, must be re-

moved, and replaced by others; and in this way the process must be carried on till nearly the whole of the colouring matter is withdrawn, after which, the residue is put into a bag, and washed till it becomes colourless. As thus obtained, it has all the properties of fibrin got from other sources.

Since fibrin is thus procured from blood, it is evident, that it must exist in it either fluid, or in minute globules, in which state it continues as long as it remains in the circulating system; but when the blood is drawn, it begins to assume its solid form, and hence the cause of the coagulation. The time at which this commences varies according to circumstances, but in general it begins in about 3 or 4, and is completed within 8 minutes. Though this may be stated as the time required to effect the coagulation, yet it may be shortened or prolonged by different means. Dr Scudamore found, that by keeping it at an elevated temperature, it went on more rapidly than usual, whereas when it was reduced, it proceeded slowly; and in one instance when it was kept at 40, it required an hour to complete it, though part of the same fluid, the temperature of which was not allowed to sink below 60, became quite firm in five minutes. *(Scudamore on Blood.)* The state of the vital powers also influences it materially. When the person from whom the blood is taken is in good health, it goes on more slowly than when he is weak. The last portions drawn also coagulate more quickly than the first, and especially if syncope, or a tendency to it, supervenes. Substances mixed with the blood have also an effect on it; solutions of sea salt, sal ammoniac, nitre, and some others, prevent it, whereas those of some of the metallic compounds accelerate it.

During the coagulation, it has been stated by Dr Gordon, that heat is evolved, (An. of Ph. iv.); but Dr Davy (Journ. of Science ii.) denies that this is the case, the rise of the thermometer in Gordon's experiment, being owing to some foreign cause. It has been ascertained, however, by others, that blood, which may be supposed to be at

about 98, when drawn, cools more slowly than other fluids brought to the same temperature; from which it would appear that heat is really evolved during the change.

It has been asserted by some, that carbonic acid gas is disengaged during the coagulation, but very different results have been obtained by other chemists. Brande, Scudamore, and others, state that, when kept *in vacuo*, a gaseous matter was evolved, which, from its rendering lime water turbid, must have been carbonic acid; while Dr Davy and others, have failed in obtaining it under similar circumstances.

With respect to the cause of the coagulation, physiologists are by no means agreed. It has been successively accounted for, by the cessation of the state of agitation in which it is constantly kept while circulating through the body, to the reduction of temperature, and to similar causes; the first of which opinions is still maintained by Prevost and Dumas, in the paper already alluded to, (An. de Ch. et de Ph. xxiii.) They say that they have found, by microscopic observations, that blood consists of serum, holding insoluble corpuscles in suspension, composed of a central colourless spheroid, surrounded by a thin transparent membrane of a red colour, and from which it is easily separated. They account for the coagulation by supposing, that when the movement of the blood ceases, the globules are drawn together, and thus in a great measure entangle the red membrane which remains in the clot. This is at variance, however, with the fact, that blood when removed from the body is coagulated, though kept constantly agitated. The same is the case also with reduction of temperature, which, instead of promoting, retards the change. These opinions have therefore been abandoned, and the fluidity is now supposed to be occasioned, either by a *principle of vitality* inherent in the blood itself, or by the *impress of vitality* it receives from the vessels through which it circulates.

From what has now been said, blood, it is evident, is a

very heterogeneous fluid. Its component parts, according to the account given of it, are water, albumen, fibrin, muriates of potass and soda, sulphate of potass, sub-carbonate of potass, lime, phosphates of lime and of magnesia, oxid of iron, and muco-extractive matter, *(Acetate of soda.)* In addition to these, sub-phosphate of iron has also been mentioned; but its existence is denied by Berzelius, who, though he admits the presence of iron, thinks that the phosphoric acid with which it is supposed to be in union, is formed during the process of analysis.

The different re-agents produce effects on blood, taken in its *entire state*, corresponding to those occasioned on the substances of which it is composed.

When exposed to heat, the watery part is driven off, and a dark coloured substance is left, which in a humid atmosphere becomes putrid, but in a dry one may be kept unchanged. If the residual matter be exposed to a high temperature, it is decomposed with inflammation, and the emission of a disagreeable odour; the products being carbonate of ammonia, a fetid oil, hydro-cyanic and phosphoric acids, and a residue consisting of saline matter.

From the changes which it thus undergoes, and the formation of cyanogen, hence the method of forming the ferro-cyanate of potass, as already described, the carbon and nitrogen uniting to form cyanogen, which with the iron produces the compound radical that is supposed to combine with the hydrogen, to generate the hydro-ferro-cyanic acid, (p. 13.)

Blood is soluble in water. Hence if, when recently drawn, it is mixed with it, it does not coagulate; but if the solution be exposed to heat, a flaky precipitate is formed.

The acids, when mixed with blood, render it dark coloured, and produce coagulation of its albumen. The alkalies, on the contrary, as they dissolve albumen, do not affect it, but alcohol and infusion of tannin produce changes similar to those of acids.

It has been already stated, that blood varies in its ap-

pearance, according as it is taken from the venous or arterial system. When from the former, it is *dark purple*, but from the latter *bright red*; from which it is evident, that it must undergo changes during its passage through the vessels. If it be examined as it proceeds from the heart in its way to the lungs, it is purple, but as it passes from them to the heart, it is red, so that the conversion from venous to arterial must go on in the lungs, and is therefore occasioned by respiration.

Respiration. During this process, the air which is received into the lungs, and almost instantly expelled, undergoes particular changes, by which its properties are altered; for it is no longer able to support combustion, which was first ascertained by Black, to be owing to its containing carbonic acid, as is easily proved by blowing through a tube into lime water. After Dr Black had proved the formation of carbonic acid during the act of respiration, numerous experiments were made by different chemists, to ascertain its quantity, and that of the oxigen consumed; but the results were discordant, owing to some using too little air, to others having inclosed the animals in it, by which the products were affected by cutaneous perspiration. Other circumstances also, as diet, and the state of circulation, caused sources of error in the experiments.

Crawford and Lavoisier were the first who experimented on the subject. The former found, that when an animal was confined in oxigen gas, 40.86 cubic inches of carbonic acid were evolved, and 56.86 of oxigen consumed, (Crawford on Animal Heat.) Lavoisier, from experiments performed in a similar way, concluded that, for each 26 grains of acid generated, 23.2 of oxigen disappeared, (An. de Ch. v.); so that from both of these it would appear, that more oxigen is removed than is necessary for the formation of the acid gas. Other chemists, nearly about the same time, arrived at a similar conclusion, but the experiments of Allen and Pepys, (Ph. Tr. 1809,) performed on a large scale, and in which every source of error seems to have been cautiously avoided,

shew the inaccuracy of these results. They found that in *natural respiration*, there was no diminution in the volume of the respired air, at least it was so trifling, as to be altogether unworthy of notice; consequently there was not more oxigen consumed, than there was carbonic acid formed, this elastic fluid, it is well known, occupying the same volume as the oxigen employed in its formation. The proportion of acid in the expired air, they found, amounted, during natural respiration, to 8.5 per cent. by volume. When the same air was frequently breathed, it was 9, and even in some instances so high as 10 per cent., but they could not by continued inspirations make it go beyond this. The actual quantity formed by each inspiration, or during a certain time, of course must vary, according to the bulk of air inspired, and the frequency of the inspiration.

The experiments of Dr Edwards, (de l'Influence des Organs Physiques sur la Vie,) confirm, generally, those of Allan and Pepys; at the same time, however, they shew that the acid formed is not always equal to the oxigen consumed, as was particularly the case in some of the lower animals.

Lavoisier was induced to believe, that the nitrogen of the air served no particular purpose during respiration. Davy, however, found in his experiments, that a little of it was absorbed, (Researches on Nitrous Oxid); while Allan and Pepys, on the contrary, observed that in some of their trials there was actually an evolution of it, particularly in those instances when oxigen alone was breathed. In natural respiration, however, the last chemists found that there was no diminution in the volume of the respired air; and, as the oxigen removed was supplied by its equivalent of carbonic acid, they, of course, concluded that there was no change on the quantity of nitrogen. Edwards, in the publication alluded to, has however shewn, that though at times the nitrogen does not suffer any change, yet occasionally it is, in some instances, increased, in others diminished. He concludes, from his numerous experiments, that it is actually *ab-*

sorbed into the system, and afterwards discharged; and that each of these actions is regulated by the constitution, habits, and circumstances of the individual, and by the influences to which he may be subjected, the absorption being sometimes to a small extent, while the exhalation is considerable; and, on the contrary, the exhalation being sometimes slight, while the absorption is great. When the exhalation predominates, there is an increase in the volume of nitrogen; and when, on the contrary, the absorption preponderates, there is a diminution. If the one equals the other, of course there is no alteration in its quantity.

Watery vapour is always exhaled from the lungs. This was at one time supposed to be formed by the union of the oxigen of the air with the hydrogen of the blood; an opinion now abandoned, as it has been proved, by the experiments of Allan and Pepys, that the whole of the oxigen goes to the production of carbonic acid. We are to consider the vapour, therefore, merely as an exhalation from the surface of the membrane of the air-cells. According to Dr Murray, about 3 grains of water are given off in a minute, during natural respiration.

Two theories have been advanced to account for the changes induced by respiration. By one it is supposed that the carbonic acid, which previously existed in the blood, is evolved in the air cells, and that the oxigen of the atmospheric air is absorbed, and being carried through the circulating system, gradually enters into union with the carbon, to form carbonic acid. By the other it is supposed, that the oxigen of the air is not absorbed by the blood, but at once combines with its carbon when in the lungs, to produce the carbonic acid, which is instantly disengaged. With respect to the last, which is generally received, two opinions have been entertained of the manner by which the acid gas is generated. Some imagine that the oxigen passing through the membrane of the air cells, combines with carbon, and comes off in the form of carbonic acid; while others suppose that the carbon in vapour is evolved from the blood, and passing

through the membrane into the cells, forms with the oxigen the acid gas, (Ellis on Respiration.)

Different circumstances cause a variety in the phenomena of respiration. Crawford, and Lavoisier and Seguin, found that less oxigen is consumed, and consequently less carbonic acid formed at a high than at a natural temperature; but during digestion and exercise, the quantity was greater than natural. Dr Prout, (An. of Ph. xiii.) has also shewn, that speaking, and the depressing passions, lessened the quantity of carbonic acid; and from experiments which I have performed, (Inaug. Dissert. 1814.) the same was occasioned by the use of vegetable food, and spirituous fluids. Dr Prout has likewise found, that the quantity varies at different times, being more abundant during the day than at night.

The changes that the blood and air undergo during respiration, serve important purposes in the animal economy. The superabundant carbon of the system is carried off. It is supposed also to be owing to them, that animals possess the wonderful faculty of preserving their temperature above that of the surrounding medium.

There are strong proofs in favour of this opinion. It is well known, that whatever raises the temperature of the body, as violent exercise, increases the consumption of oxigen in the lungs; whereas when an animal is kept in a medium warmer than itself, little or no change takes place during the circulation; the venous is nearly of the same colour as arterial blood, and scarcely any oxigen disappears, the supply of heat required being small. In those animals in which the organs of respiration are large, the temperature is not much changed by alterations in that of the surrounding medium; but in those in which they are small, and in which of course the quantity of oxigen consumed must be trifling, it varies according to circumstances. Dr Crawford was the first who advanced a theory to account for the production of animal heat, and the uniform distribution of it over the body, (Crawford on Animal Heat.) In examining the ca-

pacity of venous and arterial blood, he found that there was a considerable difference between them, the former being 892, and the latter 1030, compared to water as 1000. He therefore supposed, that by the union of the carbon of the former with the oxigen of the air, by which carbonic acid is generated, heat is disengaged; but as by this action the venous blood is instantly arterialized, the capacity is increased, so that the heat, instead of becoming sensible, is absorbed, and thus, though there is actually the production of it in the lungs, yet their temperature does not rise. The arterial blood being carried through the circulating system, arrives at the extreme vessels, where it is gradually again converted to venous, by which its capacity must be diminished, and heat evolved; and as this change goes on slowly, it is equally distributed, and the temperature thus kept always nearly the same. The venous blood, loaded with carbon, is in this state brought again to the lungs, again to be arterialized, and give rise to the evolution of heat. This opinion of Crawford, provided the facts on which it is founded are correct, will account satisfactorily for the production of heat, and its uniform distribution over the body. Subsequent experimenters do not however allow, that there is really such a difference in the capacity of venous and arterial blood, as stated by him; indeed, according to Dr Davy, there is little or none, (Ph. Tr. 1814.)

Allowing Davy's experiments to be correct, the distribution of heat, supposing it dependent on respiration, may be accounted for in two ways: That when evolved in the lungs, the temperature of the arterial blood is raised, and in this state it is conveyed to the different parts of the body, to give out that which it had received; and this opinion Davy himself is induced to adopt, for on examining the temperature of venous and arterial blood, he found the latter in the carotid artery, to be higher by 1.5, or by 2 degrees, than the former in the jugular vein. The other method of accounting for the production and distribution of heat, is founded on the supposition, that

the carbonic acid is formed not in the lungs, but in the arterial blood during its circulation, by its carbon uniting with the oxigen absorbed by it from the air, in its passage through these organs, the heat generated by the formation of the acid, being of course communicated to the surrounding parts.

Though it is generally admitted, that the source of animal heat is dependent on the changes produced on the blood by respiration, and during its passage through the circulating system, it has been attempted to be proved, that these have no share whatever in its production, but that it is to be ascribed to *nervous influence.* Mr Brodie, who advocates this opinion, (Ph. Tr. 1811,) asserts, that by keeping up artificial respiration in animals recently killed, and by which the usual changes were induced in the lungs, oxigen being absorbed, and carbonic acid evolved, the venous being at the same time changed to arterial blood, the temperature fell, proving, as he supposes, that there was no generation of heat. In one instance, that of a rabbit sunk in 30 minutes from 97 to 90, while that of another killed at the same time, and in which the respiration was not continued, fell from 97 to 91. These experiments of Mr Brodie, however, if maturely viewed, will be found rather to strengthen than invalidate the opinion, that the production of heat is dependent on respiration. In those, for example, in which it was kept up, the lungs were constantly exposed to a renewal of cold air, which must have cooled the animal, not merely by the direct abstraction of caloric, but also by causing evaporation from the surface of the lungs; and as the temperature did not fall below that of the animals in which artificial respiration was not performed, we are warranted in concluding that heat was disengaged.

Though, however, these experiments do not in the least militate against the generally received opinion, it must not be supposed that the whole of the heat by which the temperature of animals is kept above that of the surrounding medium, is evolved by the changes produced by respiration. It is well known, that under cer-

tain circumstances, oxigen is absorbed through the skin, and carbonic acid disengaged *, so that this may probably give rise to the production of heat; besides, it is not at all unlikely, that the different changes which the blood is constantly undergoing, during the production of the animal solids and fluids, may have some share in the disengagement.

Fluids subservient to Digestion.—Saliva, Gastric and Pancreatic Juice, Bile.

Saliva.

Saliva is a transparent colourless fluid like water, but rather more viscid, and, as usually procured, it is frothy, from the admixture of atmospheric air. It is destitute of taste and smell. Its sp. gr. is 1008. When heated in close vessels, it gives off watery vapour, and a solid residue remains, consisting of saline ingredients and a little animal matter.

When exposed to air, saliva seems to absorb oxigen, and become thicker. When mixed with water, a flaky matter is precipitated. The acids coagulate it. The alkalies make it give out the odour of ammonia. Nitrate of silver throws down a precipitate of phosphate and muriate of silver, and oxalate of ammonia precipitates lime. Muriate of mercury does not affect it; but sub-acetate of lead throws down a copious precipitate.

* Though different statements have been given with respect to the nature of cutaneous exhalation, the experiments of Collard de Martigny, (Med. Rep. N. S. v.) prove satisfactorily, that carbonic acid is disengaged through the skin; and he accounts for the discordance in the results of the experiments of others, by its being evolved only at certain times.

According to Berzelius, the composition of saliva is,

water,	929.9
mucus,	1.4
alkaline muriates,	1.7
soda,	.2
lactate, (acetate of soda,) animal matter,	.9
peculiar animal matter,	2.9
	1000.0

When saliva is exposed to the galvanic influence, a precipitate collects around the negative wire, from which Mr Brande infers that it contains albumen, even though the usual tests cannot detect it; and Tiedemann and Gmelin (Sur la Digestion) assert, that besides the usual ingredients, they have detected in it osmazome and sulpho-cyanate of potass; the latter being indicated in it by the red colour which it gives to per-salts of iron, a property peculiar to sulpho-cyanates.

The same chemists state, that the saline matter procured by the evaporation of saliva, and incineration of the residue, consists of carbonate, phosphate, sulphate, and muriate of potass, phosphate of lime, and a minute quantity of carbonate of lime and of magnesia. In the saliva of sheep there is also sulpho-cyanate, and the carbonate of potass is in such quantity as to cause effervescence on the addition of an acid. The saline ingredients in that of hogs is the same, with the exception of the sulpho-cyanate, which they could not detect in it.

Tartar, the incrustation formed on teeth, is supposed to be a deposit from saliva. According to Berzelius, it consists of

earthy phosphates,	79.
undecomposed mucus,	12.5
peculiar salivary matter,	1.
animal matter soluble in muriatic acid,	7.5
	100.0

Gastric Juice.

The food, after being subjected to trituration, and mixed with saliva, is received into the stomach, where it undergoes the process of digestion, by which it is converted to a pulpy mass called *chyme*. It was at one time imagined that digestion was accomplished by the pressure exerted on the food by the coats of the stomach; at another time, that the changes were the result of fermentation. It is now, however, allowed, that they are occasioned chiefly by the chemical action of a fluid secreted from the coats of the stomach, called *gastric juice*.

We cannot place much confidence in the experiments made with the view of ascertaining the properties of gastric juice, owing to the difficulty, or rather the impossibility, of procuring it pure. Spallanzani obtained it by forcing hollow balls, with their sides perforated, and containing pieces of sponge, into the stomachs of animals that had been kept for some time without food. The sponge, when withdrawn and squeezed, yielded a fluid, supposed to be gastric juice. It may also be obtained by inducing vomiting, after an individual has been kept for some time fasting.

As thus procured, it is transparent and colourless, having a saline taste, and without acidity. According to Spallanzani, it does not undergo putrefaction, and prevents other substances from putrefying. It is precipitated by nitrate of silver, and it seems to contain a minute quantity of albumen, gelatin, and mucus.

We are better acquainted, however, with the properties of gastric juice when in the stomach, several curious and interesting experiments having been performed by Reaumeur, Spallanzani, (Dissertations, vol. i.) and Steevens, (Inaugural Dissertation.) When substances commonly used as food were inclosed in metallic balls, with their sides perforated, and forced into the stomach, they were dissolved, and in this way the solvent power of the fluid has been proved, because they were com-

pletely excluded from pressure; indeed, so great is its power of dissolving, that it has been supposed by Mr John Hunter, that the erosions sometimes found in the coats of the stomach of those who have died suddenly after fasting, were occasioned by it.

The gastric juice has been found to differ in different animals, according to the food on which they are accustomed to live. In general, that of the carnivorous class produces little if any effect on vegetables, while that of the gramenivorous does not affect animal matter. That of man dissolves both animal and vegetable bodies, man being omnivorous.

It is well known, however, that animals may be brought to live on food altogether different from that which nature intended for them; a change, however, which must be effected very cautiously. Hence carnivorous may become gramenivorous, and the gramenivorous carnivorous animals, from which it is evident that the gastric juice changes its nature, since it becomes a solvent of food which it could not previously dissolve.

Though gastric juice has thus been found to have a very powerful effect on the different substances received into the stomach, it must not be supposed that digestion is occasioned merely by its solvent powers; the pressure exerted by the muscular coats of the stomach must have its influence, as happens more particularly in the lower animals, as in birds, which are furnished with a strong muscular organ, by which the aliment is subjected to powerful pressure, and thus rendered more easily attacked by the gastric juice.

Gastric juice has the property of coagulating milk; hence the use of the decoction of the stomach in procuring curd, *(See Milk.)*

In addition to the gastric juice found in the stomach, Dr Prout has shewn that there exists a considerable quantity of free muriatic acid, the evolution of which seems to commence almost immediately after the introduction of food, (Ph. Tr. 1824,) a fact which has been

confirmed by the experiments of Tiedemann and Gmelin, (Sur la Digestion,) who have found not only muriatic, but also acetic acid, and which, they are of opinion, are agents employed in the solution of the food.

When the food has undergone the process of digestion, it is converted to *chyme*, in which state it passes into the intestinal tube, where it undergoes new changes. Being acted on by the pancreatic and biliary fluids, part of it becomes *chyle*, which is absorbed by the lymphatics, the remainder is *excrementitious*, so that digestion, though begun in the stomach, is finished in the intestines.

Pancreatic Juice.

Pancreatic juice has been examined by Tiedemann and Gmelin, who have found it to contain albumen, a substance like acid, salivary matter, and osmazome, with the same salts that exist in saliva, with the exception of sulpho-cyanate of potass.

Bile.

The chemical examination of bile has engaged the attention of many distinguished chemists, particularly of Cadet, Thenard, and Berzelius; and more lately, Tiedemann and Gmelin, in their work on Digestion, have pointed out many new facts concerning it. Though the bile of different animals has been subjected to analysis, yet that of the ox is the one that has been most examined; indeed, from it the properties have been generally described.

Ox bile has a yellowish green colour; an intensely bitter taste, and a faint peculiar odour. It has an unctuous feel, and is of a thickish consistence, though this varies much according to the time it has continued in the gall-bladder, as it gradually becomes thicker when retained in it, owing to the absorption of its watery part, so that its sp. gr. must also vary. It is in general from about 1020 to 1030. When litmus paper is put into it, it be-

comes blue, shewing that it contains uncombined alkali, which has been found to be *soda*.

When kept for some time exposed to the air, it emits a fetid odour, and soon runs to putrefaction.

When subjected to heat in close vessels, a watery fluid, having the odour, but not the taste of bile, comes over; the residue, amounting to about 1-10th, is dark-coloured and tenacious, having a bitter taste, and being deliquescent, and soluble in water. When the temperature is high, it is decomposed, and the usual products are given off, but with rather more empyreumatic oil than is produced by other animal substances in general. A large quantity of charcoal is left, containing the saline ingredients, which, according to Thenard, (Mem. d'Arcueil, i.) are phosphate, muriate, and sulphate of soda, phosphate of lime, with free soda, and a trace of iron.

Bile readily unites with water.

It is easily decomposed by acids, by alcohol, and some of the compound salts, by which its component parts are discovered.

By the addition of muriatic acid, a yellow precipitate is formed, consisting of a peculiar *yellow matter*, and a *little resin*. On evaporating the fluid after filtration, a flaky substance is procured, which, from its inflammability and solubility in alcohol, is considered similar to *resin*. It has, in a great measure, the colour and taste of bile. It may also be obtained, though not pure, by the addition of alcohol, by which the albuminous and yellow matter are precipitated.

The yellow matter thrown down in these different experiments, is supposed also to be peculiar to bile. Though insoluble, yet, when acted on by soda, and the other substances present in bile, it becomes soluble. It is supposed to be the principle which causes the bile to run so easily to putrefaction, and it appears also as an ingredient of biliary concretions. In some of its properties it resembles albumen.

By the addition of Goulard's extract, the yellow matter, and resin, are precipitated, and a peculiar substance

is left in solution, for the discovery of which we are indebted to Thenard, (Mem. d'Arcueil, i.) though it had been previously noticed by Cadet, (Mem. de l'Acad. de Sciences 1767.) He gave it the name of *picromel*, (πικρος, bitter, *mel*, honey.)

The process by which Thenard at first succeeded in procuring it, consists in adding sub-acetate of lead to bile, by which the albumen and colouring matter are deposited. On filtering the fluid, and passing sulphuretted hydrogen through it, the superfluous lead is removed, and picromel with acetate of soda, formed by the union of the free soda and the acid of the metallic salt, are held in solution, and are procured by evaporation. To separate these, the residue, after being dissolved, is mixed with sugar of lead, by which the picromel and oxid are deposited, and from which the latter is thrown down, by dissolving the precipitate in vinegar, and exposing it to the action of sulphuretted hydrogen; the former is left in solution, and may be obtained by evaporation.

Picromel, as thus procured, is not however pure, it still retains a little resin, but from which it may be freed by repeated precipitation by sub-acetate of lead, and removal of the excess of metal by sulphuretted hydrogen; in fact, this forms the best process for procuring it; first to add sugar of lead to bile, and into the fluid, after filtration, to throw Goulard's extract, by which picromel, oxid of lead, and resin, are thrown down. Having washed the precipitate, and suspended it in water, the lead, and greater part of the resin, are separated by the transmission of sulphuretted hydrogen; but it requires this last part of the process to be frequently repeated, so as to remove the whole of the impurities.

Picromel has a peculiar sweet taste, but leaving a disagreeable bitter sensation. It is soluble in water and in alcohol. It combines with acids, and forms compounds, which are in general insoluble. It unites also with some of the metallic oxids, and forms insoluble compounds; hence its watery solution is precipitated by salts of mercury and of iron. It is not precipitated by infusion of

nut-galls. It has the power of dissolving resin; indeed, it is chiefly by its agency that the resin is held in solution in bile, for, when united with it, it forms a substance having the peculiar flavour of bile. The picromel is not, however, in sufficient quantity to keep the whole dissolved, so that the free soda must also exert its influence.

Picromel has been analysed by Thomson, who states its composition to be, (An. of Ph. xiv.)

carbon,	54.53	or	5 atoms
oxigen,	43.65		3 do.
hydrogen,	1.82		1 do.

Such are the component parts of bile, as given by Thenard; resin, yellow matter, picromel, and salts. According to him, 800 parts were found to consist of

water,	700	phosphate of soda,	2
resin,	24	muriate do.	3.2
picromel,	60.3	sulphate do.	0.8
yellow matter,	4.5	phosphate of lime,	1.2
soda,	4	oxid of iron,	a trace

Berzelius (Med. Chir. Tr. iii.) does not allow that the statement given by Thenard of the composition of bile is correct. According to him, the yellow matter, the resin, and picromel, precipitated by the different reagents, are one and the same, to which he gives the name of *biliary matter*. Subsequent experimenters have, however, proved the inaccuracy of the opinion of Berzelius, at least with respect to the non-existence of resin in bile, though it must be allowed, that by the process described by Thenard, it is doubtful if he succeeded in effecting a complete separation of the picromel and resin.

The latest analysis of bile, is that by Tiedemann and Gmelin, (Sur la Digestion,) who confirm the results of the experiments of Thenard, but who, at the same time, have added to the list of its contents. According to them, besides the substances mentioned by the French chemist, it contains several other ingredients. Ox bile, they state, consists of a volatile odoriferous matter given off by the application of heat, cholesterine, resin, asparagin, picromel, colouring matter, a substance containing

nitrogen soluble in water and in alcohol, a substance insoluble in water, but soluble in warm alcohol, probably gliadine, a matter supposed to be osmazome, a substance having the odour of urine when heated, caseous matter, and mucus. Besides these, there were found also carbonate of ammonia, margarate, oleate, acetate, bicarbonate, phosphate, muriate, and sulphate of soda, and phosphate of lime, with soda in union with an acid which they call *cholic*, from its being peculiar to bile. The water amounted to 91.5 per cent.

Human bile differs materially from that of the ox. It is sometimes of a greenish, at other times of a brownish colour. It has a bitter taste, and, though limpid, usually contains a considerable quantity of *yellow matter* suspended in it. By evaporation it yields a residue amounting to about 1-11th of its weight, and which consists of the same ingredients as that from ox bile. The acids throw down albumen and resin. Thenard could not, however, detect in it any picromel, but others have succeeded in obtaining it. The following is the analysis by Thenard in 1100 parts:

water,	1000
yellow matter floating in the bile, from 2 to 10,	10
albumen,	42
resin,	41
soda,	56
salts,	45
	1100

The ingredients found in human bile by Tiedemann and Gmelin, differ from those stated by Thenard. They were picromel, resin, colouring matter, cholesterine, besides the salts, in which were found oleic acid.

Bile is considerably altered by disease. Thenard remarks, that that secreted by an enlarged liver contained little resin, and in the advanced state of the complaint, it had a great deal of albumen, and little of the peculiar matter which gives it its taste.

Concretions are sometimes formed from the bile, during its retention in the gall bladder, in which they occasionally remain; in other instances, they pass from it into the ducts, and being retained there, give rise to jaundice. They are of two kinds. The most common are white, and have a crystalline appearance, being formed of concentric layers, with in general a nucleus of inspissated bile. They are sometimes of the size of a pigeon's egg, and only one is in general found at the same time in the bladder. The matter of which they are composed melts when heated, and resembles wax. It is soluble also in alcohol, from which it is deposited when the temperature falls. From these properties, Fourcroy considered it as adipocire, but Chevreuil considers it a substance altogether different both from it and from spermaceti, and one which is peculiar to bile. He has called it *cholesterine*, (An. de Ch. et de Ph. vi.) It is of course the same as that noticed by Tiedemann, as existing in bile; indeed, Chevreuil himself asserts, that he has frequently detected it in it, (London Journal xviii.)

Cholesterine (from χολη, bile, and στιξεος, solid,) is procured, by dissolving a calculus containing it in warm alcohol, and instantly filtering, by which it is deposited when the temperature falls.

It has all the appearance of spermaceti, but is distinguished from it by requiring a higher temperature for its fusion, and by not yielding soap with alkalies. With nitric acid it forms a peculiar acid, called by Pelletier and Caventou *cholesteric*.

Biliary calculi are occasionally found, consisting of inspissated bile, and of the peculiar matter above mentioned, and in some they have been found to be almost entirely free from the latter. Gall stones are frequently met with in the ox, which are generally composed of the yellow colouring matter, with a minute quantity of inspissated bile, and as the latter is easily removed, they are much used as a yellow pigment.

Erythrogen. Another substance has been described

under the name of erythrogen, as connected with bile. It was found by Bizio in the gall bladder of a person who died while afflicted with jaundice. It was of a greenish colour, having an unctuous feel. It was insoluble in water, but soluble in warm alcohol. When put into nitric acid, oxigen gas was disengaged, and a red coloured solution was formed, the gas, according to Bizio, being evolved from the acid. A similar solution was obtained when it was acted on by ammonia, but in this case hydrogen was set free, from which it appears that the erythrogen unites with nitrogen, to form the red solution. Hence the name from ερυθρος, red. (London Journal xvi.)

Ambergris. This substance, found floating on the ocean in tropical climates, was formerly considered the excrement of those whales from which spermaceti is procured, but other opinions have been lately advanced with respect to its origin. Buillon Lagrange discovered in it what he supposed to be adipocire, but which Pelletier and Caventou have shewn to be more nearly allied to cholesterine, and hence they suppose that it is a biliary calculus, from a particular species of whale. To the peculiar matter existing in it, they have given the name of *ambreine.* It may be got by digesting ambergris in alcohol, and evaporating the solution, by which it is obtained in crystals.

It has a brilliant white colour, and is easily fused by heat. Is insoluble in water, but soluble in alcohol. When treated with nitric acid, it affords a peculiar acid, which Pelletier and Caventou call *ambreic,* (An. of Ph. xvi.)

As bile contains free soda, it forms a soapy fluid when mixed with oil, and hence its use for taking out greasy spots, for scouring wool, and for cleaning the walls of oil painted rooms. Owing to this, it is also employed for mixing colours, and for depriving ivory of its unctuous matter when it is to be used by miniature painters.

Chyle.

Chyle is taken up by the lacteal vessels, and conveyed by them to the thoracic duct, and from this into the blood, before it passes through the heart.

It is a white opake fluid, having a sweetish taste, and after standing for some time exposed to air, forming a coagulum soluble in sulphuric and muriatic acids, and in alkalies, but insoluble in alcohol and in ether.

According to Vauquelin, (An. de Ch. lxxxi.) the coagulum is intermediate to fibrin and albumen, while Mr Brande, from his experiments, (Ph. Tr. 1812,) concludes that it is similar to that obtained from milk.

The fluid part, after the removal of the coagulum, coagulates by heat, by the addition of acids and of alcohol, and hence albumen exists in it. Besides it, it contains a substance similar to sugar of milk, and the usual saline ingredients of animal fluids, phosphates and muriates of soda, and of lime.

Dr Prout has submitted to examination the chyle of two dogs, one fed on animal, the other on vegetable food, and has found them to contain the following ingredients, (An. of Ph. xv.)

	Veg. food.	An. food.
fibrin,	.6	.8
incipient albumen,	4.6	4.7
albumen and colouring matter,	.4	4.6
sugar of milk,	a trace	
oily matter,	a trace	a trace
saline matter,	.8	.7
water,	93.6	89.2

The *incipient albumen*, mentioned in the table above, is, according to Prout, a substance which by some process is ultimately converted to albumen. It is detected in chyle, by adding acetic acid to the fluid separated from the coagulum, and then heating it, by which a precipitate appears.

Milk.

Milk, the fluid destined for the nourishment of young

animals, is secreted from the vessels of the mammæ, the organs attached for that purpose to the females of the mammiferous class. Cow's milk has been generally the subject of investigation; the properties of it will therefore be first described, after which those that differ from it, in so far as they have been examined, will be noticed.

Milk, like blood, when kept at rest, is spontaneously resolved into its component parts; a thick whitish coloured substance, the *cream*, rises to the surface, leaving the milk beneath it much thinner than before.

Cream is an oily fluid, having an unctuous feel, and a sp. gr. less than that of water.

According to Berzelius, it consists of

butter, - - -	4.5
cheese, - - -	3.5
whey containing sugar of milk,	92.

and which are easily separated either by spontaneous changes, or by the action of re-agents. When, for instance, it is kept at rest, it becomes gradually thicker, till at last it acquires the consistence of cheese; and hence the method of making cream cheese, merely by putting cream into a linen bag, and leaving it there till it becomes solid.

When cream is shaken, it is resolved into its component parts. The process by which this is accomplished is called *churning*, by which two substances are obtained, *butter* and *butter milk*. In the making of butter, cream is allowed to stand for some time, during which an acid is generated. It is then put into a churn and shaken, by which the butter is gradually separated. What is left, the butter milk, has a sour taste, but by no means so much so, as that of the cream before the churning, so that a part of the acid seems to have disappeared, or been neutralized. Butter is sometimes also made from cream which has not become sour, but the process is much more tedious, the acid formed in the other case favouring its separation.

During churning, the temperature is slightly elevated, and there is in general an absorption of oxigen; hence the necessity of occasionally admitting air into the churn, otherwise the separation of the butter cannot be effected.

Butter is merely an animal oil, but, as usually obtained, is not pure. It melts at about 96, and forms a transparent fluid, which, when kept in that state for some time, deposits the extraneous matter, and then becomes like other oils. The foreign ingredients may also be separated by washing it with cold water, by which it is prevented from becoming rancid, a property it acquires from the presence of these substances.

The *oil of butter*, according to Chevreuil, (An. de Ch. et de Ph. xxii.) contains *elain*, and a peculiar principle which he calls *butyrin*, and which he describes as containing no less than three acids, *butyric*, *caproic*, and *capric*.

Milk from which butter has been taken, undergoes spontaneous changes. It becomes much sourer, and congeals into a mass of the consistence of jelly. When heated, the formation of this coagulum is hastened, and by the addition of certain substances, it very soon occurs; thus, acids and spirit of wine curdle it, which is owing to the albumen it contains being acted on by them, in the same way as blood or glair of eggs. By far the most powerful coagulator, however, is the substance called *rennet*, which is the decoction of the coats of the stomach, generally of a calf, and of course containing gastric juice. When the milk is previously heated, and rennet added, it is almost instantly coagulated, and if, after this, it is put into a bag, and subjected to pressure, a thin watery fluid escapes, and a tough white substance is left. The former of these is *whey*, the latter *curd*.

To procure curd, skimmed milk, after being slightly heated, should be coagulated by rennet, or by weak acetic acid, and having put the coagulum into a bag, it ought to be washed till the water comes off tasteless.

Curd, as thus obtained, resembles in its properties coagulated albumen. By heat it gives off the usual products, leaving, however, a very large proportion of phosphate of lime. When exposed to air in its moist state, it very soon runs to putrefaction; but when previously dried by a gentle heat, it may be preserved without undergoing any change. The acids dissolve it. Sulphuric acid, for instance, gives with it the rich red solution peculiar to albumen. The fixed alkalies also dissolve it, with the evolution of ammonia.

Curd forms the principal part of *cheese*, the richness and flavour of which depend, however, in a great measure, on the quantity of cream it contains; and hence the difference, according as it is procured from the entire, or from skimmed milk; and as the latter is generally used in this country, the cheese is by no means so rich as that made in England, where the former is usually employed; indeed, in some places a considerable quantity of cream is added to the milk. In making cheese, having obtained the curd, and freed it of its whey, the remaining part of the process is merely to subject it to pressure, by which the whole of the whey is forced out, the colour being communicated by the addition of some substance, generally annotta, which is mixed with the milk.

Though cheese may be considered as coagulated albumen, containing, however, some of the other ingredients of milk, according to Proust two peculiar substances exist in it, both of which are produced by the changes the curd has undergone. One of these he has called *caseic acid*, the other *caseic oxid*, the former being, he conceives, in union with ammonia, and giving to cheese its peculiar flavour, (Quarterly Journal, vii.)

Caseic Acid may be procured by keeping curd for some days in successive portions of water, by which phosphoric, acetic, and caseic acids are formed, and neutralized by ammonia, also generated at the same time. By evaporating the fluid, treating the saline residue with cold alcohol, and boiling the solution with carbonate of

lead, the oxid unites with the acids, causing the deposition of the phosphate, while the caseate and acetate remain dissolved. By the transmission of sulphuretted hydrogen gas through the solution, the metal is precipitated, leaving the acids, which may be separated by distillation, the acetic acid coming over.

Caseic acid, left in the retort in the process described, resembles syrup in its appearance, but becomes almost solid when kept for some time. Nitric acid converts it to oxalic, but there are also formed a little benzoic acid, and yellow bitter principle. It unites with bases, and forms salts, the most important of which is *caseate of ammonia*, being, as Proust asserts, the substance that gives to cheese its peculiar flavour. When pure, its taste is saline, but mixed with that of cheese.

Caseic oxid is obtained from the saline matter left by the alcohol in the process for procuring the acid. For this purpose, it is washed with successive portions of cold water, till it loses the taste of cheese, and then boiled, and the solution filtered and evaporated, during which the oxid is separated in thin films on the surface. These, when washed and dried, are tasteless, and insoluble in cold water, but are dissolved when the temperature is raised to 140. It is sparingly soluble in warm alcohol, being again deposited when it cools. It is insoluble in ether.

Caseic oxid is frequently found in cheese, in its separate state, in the form of small white specks. Along with caseate of ammonia, it constitutes from 30 to 35 per cent. of cheese.

The remaining constituent of milk is *whey*, which, when procured from the coagulum by repeated filtration, is a transparent fluid, having a pale yellowish colour, and a pleasant sweet taste.

Along with other ingredients, it contains a minute quantity of curd, which may be separated by allowing it to stand in a warm room for some time, or by boiling it, and filtering after it has become cold. It is then colourless, has lost its peculiar flavour, but still retains its

sweetness. When evaporated, minute crystals of a sweet substance called *sugar of milk* are deposited, and which, in its properties, resembles the saccharine matter of vegetables. To obtain it pure, the whey should be evaporated to the consistence of honey, and, when cold, dissolved in water, filtered, and again evaporated.

Sugar of milk is soluble in water, but insoluble in alcohol. When exposed to heat, it yields the usual products of *vegetable matter;* indeed, in its composition Berzelius and Prout have found it to contain the same ingredients as common sugar. It does not, according to Bucholz, undergo vinous fermentation.

Though sugar of milk resembles common sugar in many of its properties, it differs from it in its action with nitric acid, the latter yielding oxalic and malic acids, the former a peculiar one called *saccholactic.* To procure it, diluted nitric acid is poured on it, and the action promoted by the application of a slight heat, by which nitric oxid is disengaged, and a yellowish solution is formed, which, when diluted with water, yields a white sediment of saccholactic acid.

Saccholactic acid has a sour taste, and reddens blues. It is decomposed by heat, giving off the usual products. It unites with bases, and forms compounds, the properties of which have not been particularly examined.

Saccholactic acid may also be obtained by the action of nitric acid on gum; and hence the name *mucous acid,* given it by Fourcroy.

Another acid has been described as existing in milk, or rather formed during the change that it undergoes spontaneously. It is called *lactic acid,* and, according to Berzelius, is a component part of almost every animal substance. This acid is now, however, allowed, even by Berzelius himself, to be merely acetic acid disguised.

Such are the component parts of milk,—the oily matter, or butter, the caseous part, or curd, the serum, or whey, with the sugar and saline ingredients.

Milk taken from different animals has the same general properties, but varies in the proportions of the ingre-

dients. Woman's milk has a sweeter taste, contains more cream, and has very little caseous matter. Ass's milk has less cream and curd, but more of the saccharine principle. Mare's milk does not afford butter by agitation, but coagulates by the usual re-agents. That from goats and ewes resembles cow's milk.

The important uses of milk, as an article of food, are well known. Mare's milk is, by some of the Tartar tribes, made to undergo fermentation, and yield a spirituous fluid, which, however, is extremely weak, 8 pints affording only about 4 ounces of alcohol.

Tears, Mucous Fluid of the Nose, Humours of the Eye, Fluid from Serous Membranes, Liquor Amnii, Synovia, Sweat.

Tears, and the mucous fluid from the membrane of the nose, are nearly of the same composition. They are transparent and colourless, have a saline taste, and change blues to green, owing to the presence of free soda. When evaporated, they leave saline and animal matter, the former consisting of phosphates of soda and of lime, and muriate of soda. When exposed to air, they become thick. By the application of heat, a coagulum is formed, and on the addition of sub-acetate of lead, a flaky matter is deposited, so that they contain the usual salts, with albumen and mucus, the last of which is supposed to be the cause of the change they undergo when long exposed to air.

The humours of the eye, with the addition of gelatin, contain the same ingredients as the preceding fluids, only differing in their proportions. In the *vitreous* and *aqueous*, the quantity of water is great compared to the other matter, amounting to upwards of 98 per cent.; but in the *crystalline lens* there is only about 60 per cent., so that there is a considerable proportion of albumen, and hence, by boiling, it forms a white coagulum, which, according to Berzelius, resembles, excepting in its colour, the colouring matter of the blood.

The fluid from serous membranes is also of similar composition. That of the pericardium was found by Bostock to consist of water, albumen, mucus, and muriate of soda, the first forming 92 per cent.

The liquor amnii was at one time supposed to contain, in addition to these, a peculiar acid, described by Vauquelin and Buniva, under the name of *amniotic acid*; but Prout and others have not succeeded in procuring it from the same fluid. Prout, however, states, (An. of Ph. v.) that he found in it sugar of milk, in very small quantity, not exceeding, even when mixed with the saline ingredients, 3.8 in the 1000.

The *synovial fluid*, found in the cavities of joints, differs from the preceding, in containing a larger quantity of animal matter. It is viscid, but when kept for some time, becomes gelatinous, and deposits a fibrous substance, after which it regains its fluidity. Alcohol precipitates albumen, and the acids a substance similar to gluten. According to Marqueson, (An. de. Ch. xiv.) it contains about 80 per cent. of water, 17 of animal matter, and 3 of salts.

Sweat contains the usual salts, with a minute quantity of acid, supposed by Berzelius to be lactic, (acetic.)

Pus.

Pus, or *purulent matter*, varies in its appearance, according to the sore from which it is secreted. That from a foul ulcer is thin and pale-coloured, whereas that from a healing one is of a yellowish colour, and thickish consistence; its specific gravity being about 1030. It does not affect vegetable blues, but very soon becomes acid by exposure to air. When examined by a microscope, it appears to be composed of minute globules floating in a thin fluid. It is not dissolved by water; for, when shaken together, it falls to the bottom. Concentrated acids dissolve it. The fixed alkalies form with it a thickish fluid; but ammonia makes it transparent, and gra-

dually dissolves a part of it. Alcohol causes it to become thick, but does not dissolve it.

With the view of distinguishing pus from mucus, Mr Darwin has proposed different tests, but we cannot place much reliance on them. Perhaps that recommended by Grassmeyer, (Thomson's System, vol. iv.) is more to be depended on. It consists in triturating the fluid with its own weight of boiling water, and then adding an equal quantity of a strong solution of carbonate of potass. In the course of a few hours, a transparent jelly will subside to the bottom if it contain pus, but which does not appear if mucus only is present.

Urine.

Urine, the principal excrementitious fluid, has long engaged the attention of chemists and physicians, not only from the changes it undergoes, and hence giving rise to some of the most afflicting maladies to which we are subject, but also on account of its complicated nature, and the peculiar substances procured from it. The attention of philosophers was first called to it, from its having been found to yield phosphorus, the properties of which, at the time it was discovered, were considered so remarkable. For its chemical history, we are indebted to Boyle, Haller, Margraaff, Pott, Rouelle, Proust, and Klaproth; Scheele also, Cruickshank, Fourcroy, and Vauquelin, have added greatly to our knowledge concerning it; and more lately, Berzelius and Dr Prout have pointed out new facts respecting its composition, and the changes it undergoes.

Urine, even from healthy people, varies in its appearance at different times. It is in general of a pale amber colour, and when recently discharged, is transparent, but it frequently becomes muddy when kept. Its sp. gr. is from 1005 to 1033; perhaps about 1030 may be considered the average. The colour, odour, and specific gravity, vary, however, according to the quantity of drink, and the time the urine has remained in the bladder. When substances are swallowed, which cause it to be secreted

quickly, as by the use of spirituous liquors, it passes off almost colourless, and with very little odour; whereas, when retained in the bladder, it becomes darker, and the smell stronger. Particular substances swallowed, or the vapour of them inhaled by the lungs, also impart to it their peculiar odour.

Urine, when recently passed, changes blues to red, which has been successively ascribed to the presence of free phosphoric, acetic, and benzoic acid. It is now generally supposed to be owing to a super-phosphate.

Urine, as it cools, gradually deposits minute crystals of a reddish colour, shewn by Scheele to contain a peculiar acid, to which he gave the name of *uric*. The deposit varies in different individuals, and even in the same at different times. After the use of acidulous food or drink, and in those labouring under certain diseases, it is considerably increased, forming in the latter case the *lateritious sediment*, which has been lately analysed by Dr Prout, and found to consist of phosphates of lime, and of magnesia, soda in union with the acid called *uric*, and with a minute quantity of that termed *purpuric*, which is the cause of the red colour, the intensity varying according to the quantity of purpurate. A small proportion of nitric acid, according to him, also exists in it. (Prout on Calculous Diseases.)

When urine is kept for some time, it undergoes spontaneous changes, and a fetid ammoniacal odour is exhaled. The decomposition is occasioned by the elements of the peculiar principle, which gives it its particular properties, entering into a new state of combination, and generating ammonia, which causes the deposition of some of the saline matter.

Similar changes are effected by distillation. A watery fluid containing ammonia, formed by the decomposition of the principle alluded to, comes over, the urine then becomes muddy, from the deposition of flocculent matter, principally albumen; and if the evaporation be continued, it acquires a thickish consistence, and a crystalline mass is obtained on cooling. The part remaining fluid, con-

tains the peculiar principle which communicates to urine its particular properties, and which is called *uree* or *urea*. The crystalline matter is of a very complicated nature. When subjected to a strong heat, it affords carbonate and hydro-cyanate of ammonia, with a fetid oil, and when the temperature becomes high towards the end of the process, a minute quantity of phosphorus is distilled over, owing tc the decomposition of phosphoric acid, by the carbon set free from the decomposed animal matter. The residue of the incineration consists of a variety of saline ingredients, which have, however, been differently stated by authors. They are chiefly muriates of soda, potass, and ammonia, phosphates of soda, ammonia, lime, and magnesia, and phosphate of magnesia and ammonia, but these, it must be remarked, do not all exist in urine. Those containing ammonia have been formed during the evaporation and incineration by this alkali, generated by the decomposition of the uree, uniting with the superabundant acid of those which are in the state of super-salts. We find accordingly, that reagents indicate substances in solution, different from those produced by evaporation, and it is by the use of these that we are enabled to detect the ingredients existing in it.

The acids cause little change on urine. On the addition of muriatic, there is sometimes the deposition of a precipitate, which is *benzoic acid*. When the urine is evaporated, the deposit is in greater quantity. According to Scheele, this acid exists in all urine, but Berzelius states, that he could not detect it in that of children. In that of herbivorous animals, it exists in considerable quantity.

Oxalic acid throws down *lime*, which exists in the state of super-phosphate. Hence, on the addition of potassa, phosphate of lime is deposited, the excess of acid being saturated by the alkali. If, on the contrary, lime water be added, the precipitate is in much greater quantity, because the whole of the phosphoric acid is thrown down in the state of phosphate. Along with the phos-

phate of lime, there is also a little phosphate of magnesia, and, according to Berzelius, lime also in combination with *fluoric acid*, for, on the addition of sulphuric acid to the deposit, a vapour is given off, which corrodes glass, (An. de Chim. lxi.)

When muriate of baryta is added to urine, after the addition of a little nitric acid, to prevent the deposition of the phosphates, sulphate of baryta falls, so that *sulphuric acid* also exists in it, and, according to Berzelius, it is in union with potassa and soda. If, after the precipitate is removed by filtration, the fluid, with the excess of nitric acid and of baryta, is evaporated, more sulphate is deposited, from which it has been inferred, that *sulphur* exists in it, and has by the nitric acid been converted to sulphuric acid. This opinion seems to be strengthened by the fact, that Proust and Vogel found that silver exposed to urine became blackened.

Nitrate of silver, after the addition of nitric acid, causes a copious precipitation of chlorid, equivalent to *muriatic acid.*

Urine, according to Proust, contains *carbonic acid*, which was at one time supposed to be formed by the decomposition of the urea; but Brande and others have shewn, that if, when recently discharged, it be kept under an exhausted receiver, bubbles of gas come off, that render lime water turbid. Though carbonic acid has been detected in urine, there is no doubt, that the greater part of that found in deposits from it, is formed by the decomposition of the peculiar principle, and consequent production of carbonate of ammonia, which, acting on the salts of lime, gives rise to the generation of carbonate of lime.

Acetic acid, it is mentioned also by Proust, exists in urine, but later chemists do not allow the accuracy of his conclusion, supposing either that it was formed dur- the process followed in detecting it, or that the acid obtained was not acetic, but *lactic acid.* With respect to this peculiar acid, mentioned by Berzelius as an ingredient in almost every animal substance, it has been al-

ready stated, that Berzelius himself allows, that it is merely the acetic disguised by the presence of some other matter, so that we are to consider the statement of Proust as correct, that urine does contain *acetic acid.*

Silica, according to Berzelius, is also an ingredient of urine, and may be detected by evaporating it, dissolving the extract in alcohol, and afterwards in diluted muriatic acid, by which a powder is left, which, when fused with soda, forms glass.

In addition to the saline ingredients already mentioned, there is a considerable quantity of *animal matter.* Infusion of nut-galls throws down a precipitate generally allowed to be *gelatin ;* and that *albumen* is present, is shewn by the fluid becoming muddy when heated; indeed, in some cases there is a sufficient quantity to cause coagulation, as in the urine of those afflicted with dropsical diseases, and also of those subject to dyspepsia. Urine also contains *mucus*, the quantity of which varies according to the time it has remained in the bladder. It may often be separated by filtration, but even after this, it is sometimes also deposited as the temperature falls ; indeed, the lateritious sediment frequently contains a considerable quantity of it, for on treating it with acetic acid, mucus is dissolved. Besides the ingredients mentioned, urine contains also two principles peculiar to it, *uree* and *uric acid.*

It is difficult, when so many substances exist together in a fluid, to find out their state of combination; accordingly, very different accounts have been given of the saline ingredients of urine. During the evaporation of a fluid containing salts, new affinities are brought into play, and compounds altogether different from those existing in it are procured. But another difficulty presents itself, with respect to urine. The uree, during the evaporation, generates ammonia, and thus causes the decomposition of some of the compounds, and the formation of others. Hence, instead of free uric and benzoic acids, urate and benzoate of ammonia are obtained; and in place of the super-phosphates, neutral phosphates, and

ammoniaco-phosphates are deposited. It is evident from this, that the substances procured must vary materially, according to the mode of analysis.

The latest analysis is by Berzelius. According to him, 1000 parts contain

water,	933.00
urea,	30.10
uric acid,	1.00
phosphate of ammonia,	1.05
muriate of do.	1.5
sulphate of potassa,	3.71
sulphate of soda,	3.16
phosphate of soda,	2.94
muriate of soda,	4.45
earthy phosphates, with fluate of lime,	1.00
lactic (acetic) acid, lactate (acetate) of ammonia, animal matter soluble in alcohol, uree not separable from the preceding,	17.14
mucus of the bladder,	0.32
silica,	0.03

(Med. Chir. Tr. iii.)

The urine of inferior animals differs considerably from that described. In all it contains urea, but in the herbivorous class, there does not seem to be any uric acid; instead of which, there is a considerable quantity of benzoic. That of the horse is of a white colour, and has a peculiar odour. When exposed to air, it acquires a crust of carbonate of lime on its surface, and ultimately becomes milky, from the deposition of carbonate. Urine of the cow and camel is nearly of the same composition. Urine of the lion and tiger is destitute of uric acid. That of birds, particularly those that live on flesh or fish, contain it. That of amphibious animals is in general solid, and consists almost entirely of uric acid. According to Davy, that of lizards,

which is of a butyraceous consistence when discharged, but soon becomes hard, is of the same composition; and Prout found, that that of the boa constrictor contained about 90 per cent. of it, (An. of Ph. v.)

The two substances peculiar to urine, are urea and uric acid.

Urea was discovered by Rouelle in 1773, and it was afterwards examined by Fourcroy and Vauquelin, and also by Cruickshanks. Dr Prout has more lately made it the subject of investigation, and pointed out several new facts concerning it, (Prout on Gravel, &c.)

The method recommended by Cruickshanks for procuring it, consists in evaporating urine to about a fourth, and adding nitrous acid, by which shining scales are deposited. The process of the French chemists is however preferable, because it affords it purer. The urine is evaporated to the consistence of honey, and after it is cold, four times its weight of alcohol is poured on it, and a slight heat applied, by which the urea is dissolved, and may be procured by filtration and evaporation in shining scales. These are at first of a yellowish colour, but by repeated solution and evaporation may be obtained colourless, but the process by which this is effected is tedious. That followed by Prout, consisted in evaporating urine to the consistence of syrup, and adding nitric acid, till a crystallized mass was formed, which was washed with a little cold water. Sub-carbonate of soda was then added, to saturate the acid; and the fluid, after the crystallization of the nitrate, and filtration through animal charcoal, was evaporated to dryness. The residue, when treated with alcohol, gave a solution, which, on evaporation, yielded urea pure.

Urea, as thus procured, has a fetid odour, a disagreeable acrid taste, and is very tough. When exposed to air, it speedily attracts moisture, and becomes fluid. It does not affect vegetable colours.

It is decomposed by the application of a slight heat, that of boiling water being sufficient, by which carbo-

nate of ammonia is given off; and hence an excellent test of its presence, as no other animal principle is decomposed at so low a temperature.

When subjected to a strong heat in close vessels, the usual products are given off, along with an extremely fetid oil, and benzoic acid. It is also easily decomposed when heated with peroxid of copper, by which its component parts have been ascertained. According to Prout, they are,

carbon,	19.99	1 atom
oxigen,	26.66	1 do.
hydrogen,	6.66	2 do.
nitrogen,	46.66	1 do.
deficiency,	0.03	

Urea is very soluble in water. The solution, supposing that procured by the action of alcohol to be used, is brown, but becomes lighter by dilution, when it acquires the colour of urine. When kept for some time, it undergoes spontaneous changes. It acquires an acid taste, owing to the generation of acetic acid, and carbonic acid, in the form of gas, is disengaged. By subjecting it to heat with sulphuric acid after this, acetic and benzoic acids are given off, and sulphate of ammonia is left in the vessel. When the recently prepared solution of urea is boiled, it also undergoes decomposition, and carbonate of ammonia is formed; a little acetic acid is also given off, and carbon is left.

When chlorine gas is passed through the solution, flakes, at first white, but afterwards becoming brown, are formed. When the fluid is saturated, carbonic acid and nitrogen are evolved, and nitrate, muriate, and carbonate of ammonia are found in it.

The acids have a peculiar action on urea. When nitric acid is added to its watery solution, white brilliant scales are deposited, the same as those produced by adding it to concentrated urine, as in the process recommended by Cruickshanks for preparing it. These scales, according to Prout, are urea in union with nitric

acid, but the latter is not neutralized. They are in the proportion of

acid,	47.37	1 atom
urea,	52.63	2 atoms

When the acid is added to urea itself, nitric oxid, nitrogen, and carbonic acid are evolved, and a whitish matter with a dark red coloured liquid are left, the former of which, when heated, deflagrates like nitrate of ammonia.

When the solution of urea is mixed with a fourth part of sulphuric acid, and subjected to distillation, an oily fluid is formed along with a yellow coloured liquid, in which there is acetic and benzoic acids. The residue contains sulphate of ammonia.

Muriatic acid dissolves urea without effervescence.

It is dissolved by potassa, soda, and the alkaline earths, but with the disengagement of ammonia, owing to its being decomposed, and the ingredients entering into a new state of combination. When urea and solid potassa are mixed, the temperature rises, a large quantity of ammonia is evolved, and an oily fluid is formed. If heat be applied to the residue, ammonia, and carbonate of ammonia, are evolved, along with acetic and benzoic acids. The residue, on the addition of an acid, gives off carbonic acid gas.

Urea possesses the remarkable property of altering the form of the crystals of some neutral salts; muriate of soda, when dissolved in its watery solution, crystallizing in octohedrons instead of cubes, and muriate of ammonia in cubes instead of octohedrons; and hence the cause of those obtained from urine, being of a form different from what they generally are, the urea in it acting in the same way as when they are dissolved in its watery solution.

Urea decomposes some of the metallic salts, as nitrates of mercury and silver, and also acetate of lead.

It is soluble in alcohol, even though cold, requiring only about 5 parts to dissolve it; but at a boiling heat, it does not require more than half its weight.

The facility with which urea is decomposed, is proba-

bly the cause of the changes urine so frequently undergoes in the body, giving rise to the formation of calculous substances, *(See Calculi.)*

Uric acid was discovered by Scheele, during his investigation into the nature of urinary calculi. It was afterwards examined by Bergman and by Morveau, the latter of whom called it *bezoardic acid*, a name changed by the French chemists to *lithic*, (λιθος, *a stone*,) as being an ingredient of calculi. It has more lately been termed uric, by which it is now generally designated. It has been examined also by Dr Henry, (Manchester Mem. ii. N. S.) and by Dr Prout, (on Calculous Diseases.)

It may be obtained from urine, but the process recommended by Henry is by far the best. It consists in dissolving in aqua potassæ a calculus consisting of it, and throwing it down by muriatic acid, added in excess, by which a precipitate falls, and which, after being washed with cold water, must be dried by a heat not exceeding 212. The same process followed with the urine of the boa constrictor, and which, it has been already mentioned, contains upwards of 90 per cent. of it, will also afford it pure.

Uric acid, when pure, is a white tasteless powder, soluble, according to Henry, in 1720 of cold, and in 1150 of boiling water, the warm solution, on cooling, yielding minute crystals. Prout, however, states the solubility to be much less; according to him, it requires not less than 10,000 of water. It reddens litmus, and when added to alkaline fluids, deprives them of their power of affecting vegetable colours.

It is easily decomposed by heat, yielding water holding carbonate of ammonia and hydro-cyanic acid in solution, along with carburetted hydrogen, and carbonic acid; but, at the same time, a yellow substance is condensed in crystalline plates on the cool part of the apparatus, which, as it is possessed of acid properties, has been called *pyrouric acid*. Uric acid is also decomposed when heated with per-oxid of copper, by which the propor-

tions of its ingredients have been ascertained. According to Prout, its component parts are,

carbon,	34.286,	2 atoms,
oxigen,	22.857,	1 do.
hydrogen,	2.857,	1 do.
nitrogen,	40.	1 do.

Viewing the above as its composition, the formation of the products of the destructive distillation is easily explained, more particularly with respect to the hydro-cyanic acid; for it will be perceived, that by the removal of the oxigen, the remaining ingredients are in proportions to form it, the carbon and nitrogen constituting cyanogen, which, with the hydrogen, will give out hydro-cyanic acid.

Uric acid is decomposed by the stronger acids. The action with nitric is peculiar, and quite characteristic. When the acid, diluted with about an equal quantity of water, is poured on it, a solution is formed, which stains the skin red, and which, when boiled, gives off carbonic acid and nitrogen, and a little hydro-cyanic acid, leaving minute crystals of nitrate of ammonia. When it is used concentrated, the powder is also dissolved, and the solution, on evaporation to dryness, leaves a beautiful red stain on the glass, and which must be considered a test of the presence of uric acid.

If, instead of evaporating the solution, ammonia be added, crystals of a reddish colour are deposited, which, according to Prout, contain the alkali in union with a peculiar acid, generated by the decomposition of the uric, and to which he has given the name of *purpuric acid.*

Uric acid combines with the salifiable bases, and forms compounds called urates, which may be procured by digesting the base with the acid, taking care to have an excess of the latter. The *urates* are tasteless, and do not undergo any change by exposure to air. They are sparingly soluble, the urate of ammonia, which is most easily taken up, requiring about 200 of water to dissolve it. They are decomposed by acids, which unite with the

base, and precipitate the uric acid pure; and hence the method of obtaining it.

Pyro-uric acid. The yellow crystalline sublimate, procured by the destructive distillation of uric acid, was mistaken by Scheele, who first noticed it, for succinic; but Dr Henry afterwards inferred, from his experiments, that it was a peculiar acid, formed by the elements of the other having entered into a new state of combination, but in union with ammonia, also produced during the decomposition; an opinion confirmed by Chevalier and Lassaigne, (An. of Ph. xvi.) who have succeeded in procuring it in its uncombined state. For this purpose, the sublimate, after being dissolved in water, is mixed with acetate of lead, by which the acid and oxid are precipitated in combination, and, having washed the precipitate, the latter may be removed by the transmission of sulphuretted hydrogen through water, holding the powder in suspension. The fluid, after filtration, yields, when evaporated, minute crystals of the acid.

Pyro-uric acid is soluble in cold water, and when in solution reddens vegetable blues. It is also taken up by warm alcohol, but is deposited when the fluid cools. It is decomposed by heat, and gives off the usual products of animal matter. It is soluble in nitric acid, and may be obtained, by evaporation, unchanged in its properties; a sufficient proof that it is quite different from uric, which, when its solution is evaporated, leaves a red stain on the glass. It unites with the alkalies and earths, and forms compounds which are in general soluble; and the solutions, when mixed with those of metallic salts, afford precipitates of different colours, according to the metal employed. Its composition, according to the chemists mentioned, is,

		Probably
carbon,	28.29	12 atoms
oxigen,	44.32	14 do.
hydrogen,	10.	25 do.
nitrogen,	16.84	3 do.
	99.45	
Deficiency,	.55	

Purpuric acid may be obtained by the addition of ammonia to the nitric acid solution of uric acid, and evaporating, by which red crystals of purpurate of ammonia are formed. These are next to be dissolved in a weak solution of potassa, and the fluid, after being boiled till its colour disappears, poured into diluted sulphuric acid, by which the alkalies are neutralized, and the purpuric acid precipitated. It is thus obtained in the form of a cream-coloured powder, destitute of taste and smell, and very sparingly soluble in cold water, the solution having no effect on vegetable blues. It is insoluble also in alcohol, ether, and diluted acids, but the strong ones dissolve it with decomposition. It unites with bases, and forms compounds, all of which are of a fine red colour, and hence the name of the acid. Its attraction for alkalies is so strong, that it decomposes their carbonates with effervescence, and forms purpurates. The purpurate of ammonia is most easily obtained by the solution of uric in nitric acid, and saturating the excess of the latter by ammonia. It is this which, according to Prout, is the cause of the colour of the lateritious sediment, (p. 318.) which, in some cases, has been seen as red as the purpurate produced by the evaporation of the nitric acid solution of uric acid *.

Prout has given the following as the composition of purpuric acid, (Ph. Tr. 1818.)

		Probably
carbon,	27.27	2 atoms
oxigen,	36.36	2 do.
hydrogen,	4.54	2 do.
nitrogen,	31.81	1 do.

Erythric and oxigenated uric acids. Other acids have been described as being procured from uric acid. According to Brugnatelli, (Ph. Mag. lii.) when it is dissolved in diluted nitric acid, and the solution cautiously

* There can be no doubt that *rosacic acid*, a name given by Scheele to an acid which he supposed to exist in lateritious sediment, is merely purpurate of an alkali.

evaporated, and set aside in a cold room, minute crystals are deposited, containing, as he supposes, a peculiar acid, to which he has applied the name of *erythric*, (ερυθραινειν, *to redden.*) Prout does not, however, allow the existence of this acid. He asserts that the crystals are either super-nitrate and super-purpurate of ammonia, or probably nitric and purpuric acids mixed. Accordingly, on the addition of ammonia, a purple solution is obtained, (An. of Ph. xiv.) Vauquelin, and more lately Lassaigne, on the other hand, admit so far the accuracy of the statement of Brugnatelli. The latter has found, that by the action of nitric on uric acid, a white and a red-coloured substance are formed, but which are considered to be essentially the same, the latter being disguised by the presence of colouring matter; and he is inclined to think, therefore, that the uric acid, used by Prout, and by which he obtained purple compounds, was not pure. When uric acid, free from impurities, is treated with nitric acid, as recommended by Brugnatelli, it yields a white matter, to which Vauquelin has given the name of oxigenated uric acid, (An. de Ch. et de Ph. xxii.)

Urinary calculi. There is no fluid in the body more prone than urine to undergo changes from disease. It is supposed, by Berzelius, that the office of the kidneys is to acidify some of the substances carried to them by the blood, and hence the origin of the sulphuric, phosphoric, and uric acids in urine; but when this tendency proceeds too far, other changes are induced. There is the formation of nitric and oxalic acids, the former of which, acting on the uric, may convert it to purpuric, and the latter uniting with the lime, give rise to the formation of oxalate of lime; and hence the cause of the red colour of the lateritious sediment, and the production of calculi composed of oxalate of lime and of uric acid, the latter being always found to accompany a tendency in the system to the formation of acid. On the other hand, instead of the proper acidifying power, there is a tendency to the formation of alkali, by which the excess of acid of the super-salts is saturated, and hence the

deposition of the phosphate of lime, and of the ammoniaco-magnesian phosphate.

The changes which the urine thus undergoes, gives rise to one of the most afflicting maladies to which we are subject, the formation of *stone in the bladder*.

The calculi found in the human urinary bladder, are very various in their composition. They have occupied the attention of chemists and physicians since the earliest times, and numerous opinions have been thrown out concerning their nature, all of which, however, were vague and unsatisfactory, till Scheele undertook the investigation of them. He pointed out that they consist chiefly of uric acid, which was soon afterwards confirmed by Bergman. Since then they have been successively examined by Pearson, Fourcroy, Vauquelin, and Brande; but by far the best accounts of them yet published, are by Wollaston and Marcet, that of the former in the Phil. Trans. for 1797, the latter in his Treatise on Calculous Diseases. Dr Prout (Enquiry into the Nature of Gravel) has also added greatly to our knowledge of them.

These different chemists have shewn, that the substances existing in them are numerous, but by no means so much so as those in urine. They are uric acid, phosphate of lime, phosphate of magnesia and ammonia, oxalate of lime, and animal matter, which acts as a means of keeping the others together. Besides these, however, others have been mentioned, such as silica, albumen, and carbonate of lime. Dr Wollaston has also described a peculiar substance, which he has called cystic oxid, and Marcet another, to which he has given the name of xanthic oxid, (ξανθος, *yellow*.) Wollaston has divided them into five classes.

1. Uric acid calculus.
2. Phosphate of lime, or bone earth calculus.
3. Phosphate of magnesia and ammonia, or triple calculus.
4. Oxalate of lime, or mulberry calculus.
5. Cystic oxid calculus.

The classification of Fourcroy and Vauquelin is much

more minute, containing not less than thirteen different kinds, (Mem. de l'Institut. National. ii.)

Genus I. Calculi composed chiefly of one ingredient.

Species 1. Calculus of uric acid.
2. ——— urate of ammonia.
3. ——— oxalate of ammonia.

Genus II. Calculi composed of two ingredients.

Species 1. Calculus of uric acid and earthy phosphates, in distinct layers.
2. ——— of uric acid and earthy phosphates, intimately mixed.
3. ——— of urate of ammonia and the phosphates, in layers.
4. ——— of urate of ammonia and the phosphates, intimately mixed.
5. ——— of earthy phosphates, either intimately mixed, or in fine layers.
6. ——— of oxalate of lime and uric acid, in distinct layers.
7. ——— of oxalate of lime and earthy phosphates, in distinct layers.

Genus III. Calculi composed of three and four ingredients.

Species 1. Calculus of uric acid, or urate of ammonia, earthy phosphates, and oxalate of lime.
2. ——— of uric acid, urate of ammonia, earthy phosphates, and silex.

The classification of Wollaston, though perhaps rather simple, is, with a slight addition, sufficiently minute, at least in a medical point of view.

I. *Uric acid calculi* are of a brown colour, similar to that of recently sawn fir wood. They are in general smooth, but occasionally rough. They have a fibrous and radiated texture, are round, sometimes compressed or elongated; the sp. gr. varies from 1296 to 1786, but it in general exceeds 1500. When heated, they give out the odour of ammonia, and of burning animal matter. They are insoluble in cold, but soluble in hot water. The

weaker acids dissolve them, but the most important action is with nitric, which, after dissolving them, gives, when the solution is evaporated to dryness, the red stain characteristic of uric acid. They are soluble in caustic alkaline solutions, and by the addition of an acid, a white precipitate appears.

Besides uric acid, calculi of this kind often contain a minute quantity of phosphate of lime. or of ammoniaco-magnesian phosphate, which, however, are in very minute quantity.

The *red sand* or *gravel*, passed along with urine, is of the same composition, being merely the uric acid thrown down by some excess of acid generated in the system, probably phosphoric, sulphuric, or nitric.

Calculi sometimes occur, composed of *urate of ammonia.* They are distinguished from the former, by being lighter in their colour, and more compact in their texture. Their characteristic feature, however, is giving out the odour of ammonia, by the action of potassa. They are also soluble in alkaline carbonates, which is not the case with those consisting solely of uric acid. Though calculi composed entirely of urate of ammonia are rarely found, those consisting of uric acid have frequently an admixtnre of urate, and which modifies their properties. They are easily distinguished from both of the preceding by being partially soluble in carbonate of potass, with the evolution of ammonia, while the residue is dissolved by potassa.

II. *Phosphate of lime*, or *bone earth calculus.* When calculi are composed entirely of phosphate of lime, they have a smooth surface, are of a pale brown colour, and formed of laminæ slightly adhering. When exposed to the blowpipe, they at first blacken, from the destruction of the animal matter, but soon become white, and if the heat is intense, are fused. They are soluble in diluted nitric and muriatic acid, without decomposition, for on the addition of an alkali, phosphate of lime is deposited. When the muriatic solution is evaporated, needle-formed crystals, shooting at the angles of 60 and 120, are form-

ed. Oxalate of ammonia added to the solution, after saturating any excess of acid, throws down a white precipitate, and by which they are distinguished from the other species.

Bone earth calculi have frequently an admixture of uric acid, and of phosphate of magnesia and ammonia, causing their appearance to vary, according to the manner in which they are disposed. When they contain earthy phosphates, they are white, but when with these there is uric acid intimately mixed with them, they are pale brown. These ingredients sometimes occur in concentric layers.

III. *Phosphate of magnesia and ammonia*, or *triple calculus*. Calculi very rarely occur composed entirely of triple phosphate. It in general surrounds those of uri acid, or it is in alternate layers with phosphate of lime. It is known by its fine white colour, and by its softness and spathose structure. It is easily cut with a saw, and gives a sparkling powder. When placed on burning coal, it emits an ammoniacal odour, and melts if the heat is strong. It is sparingly soluble in boiling water, which on cooling deposits shining crystals. It is soluble in acids, even though much diluted. It is decomposed by the fixed alkalies, and which affords an easy mode of analysing them. A few drops of potassa solution, poured on the powder, and slightly heated, gives off ammonia; a white powder is left, which is magnesia; and that the solution contains phosphoric acid, is proved by the addition of carbonate of ammonia and sulphate of magnesia, having, however, previously saturated the excess of potassa by muriatic acid.

When a calculus consists of triple phosphate, along with uric acid and bone earth, it may be entirely dissolved, by putting it first into acetic acid, which takes up the ammoniaco-magnesian salt, then into weak muriatic acid, to dissolve the phosphate of lime, and lastly into potassa, to unite with the uric acid.

Ammoniaco-magnesian calculi, frequently contain phosphate of lime, intimately mixed, in which case they

are easily fused by the blow-pipe into a transparent globule. This forms a sub-species of the phosphate calculi, for which, from its easy fusibility, Wollaston has proposed the name of *fusible calculus.*

IV. *Oxalate of lime*, or *mulberry calculus.* This is distinguished from the others by its colour and surface, being externally dark brown, internally light brown, and composed of concentric layers. It is very rough in appearance, resembling the fruit of a mulberry, and it is sawn with great difficulty. It exceeds other calculi in specific gravity, being from 1428 to 1976. It is decomposed by heat, and converted to carbonate of lime, and if the temperature is intense, to pure lime, the carbonic acid being expelled; at the same time, the odour of burning animal matter is perceptible. Concentrated nitric and muriatic acid, with the aid of heat, dissolve it. It is not affected by alkalies, but their carbonates decompose it, and afford the easiest mode of analysis. By boiling it with sub-carbonate of potass, oxalate of potass is formed and dissolved, and carbonate of lime deposited. In the solution, oxalic acid is detected by the addition of lime water, and lime may be found in the precipitate, by dissolving it in muriatic acid, and after saturating the excess of acid by ammonia, adding an oxalate.

Mulberry calculus occasionally contains uric acid, and sometimes phosphate of lime. In one analysed by Brande, the component parts were oxalate 65, uric acid 16, phosphate 15, animal matter 4.

Though mulberry calculi occasion the most painful symptoms, fortunately they are by no means so frequently found as the others.

V. Calculi of *carbonate of lime* have been met with very rarely. They have been noticed by Prout and some others. They are generally white, and easily broken. In some cases, however, they had the appearance of mulberry calculi, (Med. Chir. Tr. xi.)

VI. *Cystic oxid calculi.* This peculiar substance was discovered by Wollaston in 1805, and described by him

in the Ph. Tr. 1810. It has since been observed by Henry, and also by Marcet, (On Urinary Diseases.) Stromeyer has also found it in gravel discharged from the human body, and Lassaigne in a calculus extracted from the bladder of a dog. They are of a pale yellowish colour, with considerable lustre, and a certain degree of transparency. They differ from the preceding, in not being composed of layers, but of a uniform compact structure throughout. Before a blow-pipe, they emit a very offensive smell. Heated in close vessels, the usual products are disengaged, leaving a carbonaceous residue, but smaller in quantity than that from uric acid. They are insoluble in water and in alcohol, and in citric, tartaric, and acetic acids, but easily dissolved by the mineral ones, by the alkalies, and lime water. The alkaline carbonates, except that of ammonia, also dissolve them. In throwing down the cystic oxid from any of its solutions, a substance must of course be used, which does not dissolve it. Thus, from its solution in an acid, carbonate of ammonia should be used, while, when dissolved in an alkali, a vegetable acid, as acetic, ought to be employed. Cystic oxid may be obtained crystallized by the evaporation of its solution in acid, in which state it is soluble in water.

According to the experiments of Lassaigne, who has analysed it by per-oxid of copper, it is composed of

carbon,	36.2
oxigen,	17.
hydrogen,	12.8
nitrogen,	34.

VII. Two other calculi have been described by Dr Marcet. One was of a reddish colour, soluble in alkalies and in acids, the solution in nitric acid leaving on evaporation a bright yellow stain on the glass; and hence he has proposed to call it *xanthic oxid*, (ξανθος, yellow.)

The other was found to possess the properties of *fibrin*, and he has therefore proposed, that should others of a

similar nature be hereafter found, it should be called *fibrinous calculus.*

Though urinary calculi have been arranged into different classes, yet the varieties presented must be numerous, since a change of diet, and other circumstances, alter the deposit from urine. Thus, when there is in the system a tendency to the formation of uric acid, the calculus is composed of it; but if this be checked, the separation of the earthy phosphates commences, and the concretion will become covered with them. When the tendency to the deposition of the phosphates ceases, uric acid may be deposited, so that the calculus may thus consist of layers of different ingredients. The classification of Wollaston, it is evident from this, cannot, even along with those added by Marcet, include all the varieties of calculi. It has been proposed, therefore, to add one or two more, such as those containing the phosphates and uric acid in *alternate layers*, and those having the different ingredients *intimately mixed.*

Of 150 calculi analysed by Brande, (Ph. Tr. 1808,)

16 were uric acid,
45 were uric acid, with a small quantity of phosphates,
66 phosphates, with a little uric acid,
12 entirely phosphates,
5 uric acid and phosphates, with a nucleus of oxalate of lime,
6 chiefly oxalate of lime.

Of 187 analysed by Henry,

71 were chiefly uric acid,
22 earthy phosphates,
11 oxalate of lime,
39 uric acid and phosphates in layers,
16 oxalate and phosphates in layers,
11 uric acid and oxalate,
7 uric acid, oxalate, and phosphate in layers,
8 of a more compound nature,
2 cystic oxid.

300 analysed by Pearson, almost all contained uric acid, and Fourcroy and Vauquelin found it in almost every one of 500 that they examined. Silica has been discovered in only 2 calculi examined by the French chemists, both of which were mulberry, and contained about 1 per cent. The cystic oxid has been found in about 7 instances, and in one or two cases, the gravel passed along with the urine was found to consist of it.

In administering remedies in the treatment of urinary calculi, the first step is to ascertain the nature of the concretion, which must be done by a chemical investigation of any gravel that may be passed along with the urine; and for this purpose the different tests already mentioned must be applied; but as uric acid is by far the most common, it is necessary to begin to look for it. As, however, the nature of the deposit from urine is so apt to vary, the experiments must be frequently repeated, lest, by the administration of remedies, or by other circumstances, a change in the system has been induced.

It was at one time thought, that by the injection of different solvents into the bladder, the calculus might, by a chemical action, be entirely or partially decomposed, but this method has been abandoned, the substances required for their solution being so powerful as to act on the coats of the bladder itself. Great relief is, however, now obtained by the use of remedies taken by the mouth, the nature of which depends entirely on that of the concretion. When it is composed of uric acid, alkaline and earthy substances mitigate greatly the sufferings of the patient; and hence the frequent administration of lime water and of aerated alkaline waters, the bases in which neutralizing the excess of acid in the system, thus prevent the deposition of uric acid. When, however, these are carried too far, a separation of the earthy phosphates commences, because they saturate the excess of phosphoric acid; so that, instead of alleviating, they increase the sufferings of the patient, by favouring the enlargement of the stone. That a deposition of phosphates does take place when alkaline remedies are taken to too great an extent, is rendered probable by the fact, that in cases where it was known

that the calculus was composed of uric acid, it has been found, after their administration, to have acquired a coating of phosphate. When this occurs, acid remedies are found beneficial, of which the best are cream of tartar, or some of the vegetable acids, and of course these must also be given with caution, because, by their use in excess, the opposite tendency may again be brought about. As there is every reason to believe that the formation of oxalic acid in urine is owing to an acid tendency in the system, alkaline remedies may be administered in these as in uric acid cases.

Besides the changes already mentioned, urine undergoes another very remarkable one in those labouring under the disease called *diabetes mellites*. It is increased in quantity, has a pale colour, and a sweet taste. It is found to contain very little urea, but on evaporation, it yields a saccharine matter, possessing all the properties of sugar derived from the vegetable kingdom. It may be purified by solution and crystallization, and made to undergo vinous fermentation; indeed Prout has found it of the same composition as common sugar. With respect to the process by which this change is accomplished, physicians are by no means agreed, but it is generally allowed that it is owing either to a defective secretion of urea, or to its decomposition after it is secreted.

ANIMAL SOLIDS.

Skin.

The skin or external covering of the animal body is composed of three substances, the *cuticle* or *epidermis*, the *rete mucosum*, and the *cutis vera*. The *cuticle* is insoluble in water; nitric acid destroys its texture, and stains it yellow. Sulphuric and muriatic acids act on it but feebly. The alkalies and lime dissolve it, the latter, however, slowly, so that in this respect it resembles coagulated albumen.

The properties of the *rete mucosum* have not been ascertained. It is generally allowed to be that part of the skin which gives colour to the inhabitants of different nations. Its colour in Negroes may be banished by chlorine, but it returns in the course of a few days.

The *cutis* or *true skin*, is a dense substance, which by maceration affords albumen; when long boiled in water, it is almost entirely dissolved, and the solution gelatinizes on cooling, or, when evaporated, yields glue. These properties shew that it is composed almost entirely of gelatin; and hence its use in the preparation of glue, (p. 273.) and in the manufacture of leather, (p. 269.)

Hair.

The different kinds of *hair*, from the stiff bristle to the soft down, are nearly all of the same composition. When burned, it affords iron, manganese, sulphate, phosphate, and carbonate of lime, with muriate of soda, and a little silica.

Vauquelin found, that when kept in water for some time in Papin's digester, it was dissolved. The solution contained an oily fluid, which differed in colour according to that of hair, and it afforded a precipitate with tannin and acetate of lead.

Very diluted solution of potassa dissolves hair with the evolution of ammonia.

When alcohol is kept on hair, a white oily fluid is separated, and falls to the bottom, and another, which is the colouring matter, is held in solution, and may be obtained by evaporation. It differs in its appearance according to the colour of the hair from which it is procured.

From these experiments it is inferred, that hair is composed of animal matter, probably coagulated albumen, a white oil, insoluble in alcohol, the colouring oil, with the metallic and saline matter.

Feathers are nearly of the same composition. According to Hatchett, they consist chiefly of coagulated albumen.

Muscular Fibre.

Muscular fibre, or more properly speaking, *flesh*, is a very heterogeneous substance. Besides the pure muscular fibre, it contains blood, cellular substance, blood-vessels, nerves, and fat, from which it is almost impossible to free it; so that the following remarks apply to flesh, and not to the muscular fibre in a state of purity.

When flesh is well washed with cold water, part of the muscular substance is dissolved, and the blood is carried away, leaving a fibrous matter, retaining nearly the original form. The solution, when heated, coagulates, and when evaporated to dryness, and treated with alcohol, affords a substance, having a reddish colour and a peculiar odour.

When flesh, after being well washed, is subjected to the action of boiling water, a liquid oil arises to the surface, and a solution is obtained, which gelatinizes on cooling. The jelly, when treated with alcohol, also yields the peculiar substance above alluded to.

What remains after the flesh has been subjected to these various processes, has a fibrous texture, and a greyish colour. It is of course insoluble in cold and in warm water, and when dry, becomes brittle; it is therefore fibrin.

When flesh is incinerated, it leaves charcoal, with the usual salts.

These experiments shew that flesh is composed of albumen, gelatin, fibrin, and saline and earthy matter, but along with them, there is also the substance dissolved by alcohol, and which is *ozmazome*.

The proportion of the different ingredients in flesh vary in different animals, and even in the same individual according to his age. In an analysis performed by Berzelius, (Mem. d'Arcueil i.) three-fourths were found to be fluid.

Flesh forms a principal part of our food, and as both

gelatin and albumen exist in it, and as the former only is soluble in warm water, hence the difference in the nutritious quality of butcher's meat, according to the mode of cooking it. When, for instance, it is boiled, the greater part of the gelatin is extracted, and retained by the soup. When, on the contrary, it is roasted, the gelatinous matter is not removed, so that roasted meat contains both gelatin and albumen, and should therefore be more nutritious than the other; indeed, if meat be long boiled, as in making beef tea, what is left is not only little nutritious, but very indigestible, being composed almost entirely of coagulated albumen and fibrin.

The *tendons* connected with muscles are almost entirely formed of gelatin, being completely soluble by long boiling in water.

Ligaments, on the contrary, are not entirely soluble in boiling water; so that, besides gelatin, they contain probably coagulated albumen.

Membranes.

The *membranes* have been divided by anatomists into two classes, the *serous* and the *mucous*. The former are almost entirely soluble in boiling water, and may be converted to leather, by infusion of tan; so that they contain a great deal of gelatin; the latter, on the contrary, when boiled in water, do not yield gelatin.

Brain.

The substance of the brain has been divided into the outer or *cortical*, and the inner or *medullary* part, the last of which has been made the subject of investigation by Vauquelin, (An. of Ph. i.)

When brain is exposed to air, it quickly undergoes putrefaction, emitting a disagreeable odour, and acquiring a green colour, but when immersed in water, its composition is very slowly changed. When triturated with

it, a solution is obtained, which is coagulated by heat and by acids.

The acids dissolve it; nitric acid, by the aid of heat, causes a disengagement of carbonic acid and ammonia, and the formation of oxalic acid. Sulphuric acid also partially dissolves it; the solution contains phosphate of soda and ammonia, free phosphoric acid, and sulphates of ammonia and lime.

The action of alcohol is important, as affording a means of resolving brain into its component parts. When boiled on it for some time, a substance is dissolved, which, as the temperature falls, is deposited in shining scales, and in many of its properties resembles spermaceti. When the alcohol is merely digested on brain, it acquires a yellowish tinge, owing to its having taken up an oily matter which it deposits on cooling, and which, from the experiments of Vauquelin, seems to contain animal matter and phosphorus in its uncombined state, for, when freed from acid by washing, it yields phosphoric acid by combustion. The alcoholic fluid, from which this is deposited, contains ozmazome. The insoluble matter, left by the action of repeated digestion with alcohol, has all the properties of coagulated albumen.

From the above enumeration of the properties of brain, it is evident, that besides the saline ingredients, it contains albumen, fatty matter, and ozmazome. According to Vauquelin, these were in one analysis,

water, - - -	80.
fatty matter, -	5.23
albumen, - - -	7.
ozmazome, - -	1.12
phosphorus, - -	1.5
salts, - - -	5.15 = 100

Bone.

Bones are hard solid bodies which give support to the soft parts. They vary in shape in different situations, and the density of the same bone also differs in different parts.

In general, with the exception of the more porous ones, the sp. gr. is from 2 to 2.25.

When bone is subjected to a strong heat, a white porous substance, still retaining the original form, is left, which consists almost entirely of phosphate of lime.

When bones are boiled a long time in water, particularly under pressure, as in Papin's digester, a solution is obtained, on the surface of which there is a small quantity of fatty matter. The fluid, when concentrated by evaporation, gelatinizes on cooling; it therefore contains gelatin.

When a piece of bone is kept for some time in weak muriatic acid, it gradually becomes softer and softer, owing to the solution of the earthy matter and gelatin, and a substance of the original form remains. It is soft and spongy; hence a long bone, after it has been kept in the diluted acid, may be bent in any direction, or a knot tied on it. To this substance the name of *cartilage* has been given. The component parts of bone are therefore, earthy matter, fatty matter, gelatin, and cartilage.

The earthy matter, when dissolved in muriatic acid, effervesces, owing to the disengagement of carbonic acid, and the solution contains phosphate of lime, phosphate of magnesia, and muriate of lime, shewing that, in addition to the phosphates, there is also carbonate of lime. Berzelius states, that besides these, it contains fluate of lime.

The ingredients of calcined bone were, according to him, in one analysis,

phosphate of lime,	81.9	
phosphate of magnesia,	1.1	
fluate of lime,	3.	
lime,	10.	
soda,	2.	
carbonic acid,	2.	= 100.

The properties of *cartilage* are nearly the same as those of coagulated albumen. The stronger acids dissolve it, but the weaker ones have no effect on it, unless

when kept together for a very long time, in which case it is rendered much softer, and easily dissolved by water, the solution affording a precipitate with tan, and gelatinizing on cooling, so that it seems to be changed to gelatin.

The proportions of the ingredients of bone vary according to the age of the individual. The cartilage is first formed, and on it the osseous matter is gradually deposited, so that in young persons the former is in greatest quantity, but as the individual advances in life, the earthy substances increase; hence the reason why the bones of old people are more easily fractured than those of children.

The earth of bone has a powerful attraction for colouring matter, particularly madder root; hence, when this is mixed with food, the bones themselves gradually acquire a reddish tinge.

The bones of different animals, according to Fourcroy and Vauquelin, (An. de Ch. lxxii.) vary from those of man, in containing a large proportion of magnesia,—a statement confirmed by the experiments of Berzelius.

Human teeth are nearly of the same composition with bone. Hence, when put into diluted acid, the earthy matter is dissolved, and the cartilage is left. The enamel does not, however, seem to contain any of the latter, and is therefore entirely soluble in acids, but that of ox teeth contains it. The following is the composition of bones and teeth given by Berzelius.

	Dry Human bones.	Enamel of Human teeth.	Dry Ox bones.	Enamel of ox teeth.
cartilage,	32.17	—	33.30	3.56
blood vessels,	1.13	—		
fluate of lime,	2.0	3.2	2.90	4.0
phosph. of lime,	51.04	85.3	55.45	81.0
carb. of lime,	11.30	8.0	3.85	7.10
phosph. magnesia,	1.16	1.5	2.05	3.0
soda, mur. soda, water, &c.	1.20	2.0	2.45	1.34
	100.	100	100.	100.

The *hard outer covering* of shell fish differs in its composition from bone. It contains a large quantity of carbonate of lime, with a little phosphate and animal matter. *Egg shells* are nearly of the same composition.

Horn is almost entirely composed of gelatin and coagulated albumen, the earthy matter not amounting to 1 per cent.; hence it is used for yielding glue.

Bones and other animal solids, when subjected to destructive distillation, yield a large quantity of carbonate of ammonia, and hence they are employed for affording that used in some places in the preparation of sal ammoniac, (p. 438. vol. I.) When the bone is not so strongly heated, the whole of the animal matter is not destroyed, the earthy substance is left mixed with charcoal, and hence the mode of making ivory blacking, which is so much used for decolorising fluids, as in the preparation of vegetable acids and alkalies; but before using it, it is necessary to wash it well with weak muriatic acid to remove the saline ingredients.

SECTION IV.

COLOURING MATTER.

The colouring matter of the vegetable and animal kingdoms is sometimes obtained in an insulated state, but it is in general attached to some particular principle, as gum, fecula, or resin, and hence the necessity of employing different re-agents, to get it in solution, according to the nature of the substance with which it is united.

Indigo.

Perhaps the most important of colouring substances, not only from its richness, but also from its durability, is indigo, obtained from different species of *indigofera*, cultivated in the East and West Indies, and in America. To procure it from these, they are put into troughs with water, and kept at the temperature of about 80, by which they undergo a sort of fermentation, the fluid becoming muddy, acquiring a green colour, and emitting a gaseous fluid. After this has gone on a sufficient time, the water is drawn off into another vessel, and kept constantly agitated, during which a considerable quantity of the colouring matter is deposited. Lime is next added, with the view of favouring the deposition, and putting a stop to the putrefaction, and after the whole of the colour has subsided, the supernatant water is let off, and the residue dried by exposure to air, but excluded from sunshine.

Indigo is obtained from other sources, as from the

isatis tinctoria or *woad*, and the *nerium tinctorium*, the former cultivated in Britain, the latter in India.

Indigo is a soft friable substance, destitute of taste and smell, having a rich blue colour, but varying occasionally, owing chiefly to foreign admixture, derived partly from the plants from which it is procured, partly from the substances employed in its preparation. According to Bergman, 100 of indigo consisted of

pure indigo,	47
gum,	12
resin,	6
earthy matter,	22
oxid of iron,	13

The earths, he found, consisted of

baryta, 10.3 lime, 10 silica, 1.8

and according to Proust, magnesia also exists in it.

The heterogeneous nature of indigo is proved also by the action of heat, the products differing from those of other vegetable matter, the residue of the incineration yielding a large proportion of earths, and of oxid of iron. By the cautious application of heat, however, part of the pure indigo may be volatilized, as was first noticed by Chevreuil, and afterwards by Mr Crum, the latter of whom has detailed the methods of conducting the process, (An. of Ph. xv.) For this purpose, the indigo is put into a small capsule of platinum, over which another similar is placed, and the heat of a spirit lamp applied, as long as a hissing noise continues to be emitted. On the upper part of the apparatus, when cool, needle formed crystals of a brilliant copper colour are found.

Sublimed indigo, when heated to about 550, passes off in vapour of a violet, or rather reddish colour, and without leaving any residue; but if the temperature be allowed to go beyond that, there is a decomposition.

Its component parts, according to Crum, are

		Probably
carbon,	73.22	16 atoms
oxigen,	12.60	2 do.
hydrogen,	2.92	4 do.
nitrogen,	11.26	1 do.

It is insoluble in water, but warm oil of turpentine dissolves it, giving a violet coloured solution, from which it is deposited when the temperature falls.

Common indigo is also, by the action of water, resolved so far into its component parts. When digested in it, the fluid acquires a yellow colour, and on the application of heat, ammonia is evolved, and a greenish substance is precipitated, but which soon becomes blue by exposure to air. From the supernatant fluid greenish flocculi are afterwards deposited, and alcohol throws down a brownish matter having a bitter taste. According to Chevreuil, who first noticed these changes, (Journ. de Phys. lxvi.) the precipitate becoming blue by exposure to air, is pure indigo.

The acids present important phenomena with indigo. Nitric acid concentrated, acts very powerfully with it; but when diluted, the action goes on more slowly, the indigo gradually disappearing, and nitric oxid being evolved. The solution contains a peculiar substance, to which the name of *bitter principle* has been given. The process recommended by Liebeg, (An. de Ch. xxxv.) for procuring it, consists in boiling ten parts of diluted acid on one of indigo, as long as red fumes are given off, adding acid to compensate for loss, and removing any scum that may rise to the surface. When the liquid has become cold, yellowish crystals are deposited, which, after being washed with cold water, are dissolved in it by heat; and on the addition of potassa to the solution and filtration, crystals are again formed on cooling. These are compounds of the alkali and bitter principle, and may be decomposed by adding an acid to their solution in boiling water, by which the latter is deposited in brilliant yellow plates, generally of a triangular form.

The *bitter principle* thus prepared, is, by the application of heat, first fused, and then volatilized, without undergoing decomposition. When heated suddenly in air, it is kindled, and burns with a yellow flame. It is sparingly soluble in cold, but easily dissolved by boiling

water, the solution reddening litmus. It is not acted on by chlorine or iodine, nor by cold muriatic or sulphuric acid; but the last, when warm, dissolves it. It unites with salifiable bases, and forms compound salts; from which, and from its composition, Liebeg has called it *carbazotic acid*, being, according to him, composed of

carbon,	-	31.51
oxigen,	-	53.78
nitrogen,	-	14.72

Though containing oxigen and azote, the want of action with sulphuric and muriatic acids, shews that nitric acid, or oxid, does not exist in it.

The compounds of carbazotic acid and bases, called *carbazotates*, vary in their properties according to the base. Those with the alkalies and some of the earths are soluble and crystallizable, their solutions throwing down precipitates from metallic salts, which are composed of the oxid and peculiar acid. They are all decomposed by heat, the elements of the acid entering into other states of combination, and in general with explosion.

Carbazotic acid may likewise be procured by the action of nitric acid on silk.

The action with indigo and sulphuric acid is also important. When heated with it, it is gradually dissolved, forming a solution well known by the name of *Saxon blue*. On the application of heat, the indigo, according to Mr Crum, (An. of Ph. N. S. v.) is completely changed; for, on the addition of potassa, or its sulphate, a precipitate of an intense blue colour is formed, which he considers a compound of the salt, and a peculiar principle, called by him *cerulin*, which, he states, is composed of 1 atom of indigo, and 4 of water.

The precipitate, which he calls *ceruleo-sulphate of potass*, is, when dry, of a blue colour so intense, as to appear black. It absorbs moisture rapidly from the air. It is sparingly soluble in cold, but taken up in considerable quantity by warm water, the colour of the solution

being so deep, that one drop will give a blue tinge to 500000 of water.

If the action of sulphuric acid on indigo be stopped at the moment the solution changes from yellow to blue, a substance altogether different from cerulin is formed, and to which Mr Crum has given the name of *phenicin*, from its affording purple compounds with salts, (φοινιξ, purple.) It may be prepared by shaking 1 of indigo with 8 of acid in a phial, till the mixture becomes of a bottle green colour, after which it is to be diluted largely with water and filtered. The solution at first comes off colourless; but by continuing to wash the filter with water, a blue fluid passes through, which must be kept separate from the other; it contains the peculiar substance, which, by the addition of muriate of potass, is precipitated of a rich reddish purple colour. To purify it, it is washed with water, till the fluid that comes off begins to give a red precipitate with nitrate of silver.

Phenicin, thus prepared, is soluble in water and in alcohol, giving blue solutions, from which it is precipitated by the addition of any salt, whether alkaline, earthy, or metallic; but the quantity necessary to effect the precipitation varies in the different instances. Acids have no effect in preventing the precipitation.

Sulphuric acid converts phenicin to cerulin. The fixed alkalies gradually decompose it; but it is dissolved by water of ammonia, without undergoing any change in composition.

Phenicin, according to Mr Crum, is composed of the same ingredients that exist in cerulin, but in such proportions as will form 1 atom of indigo, and 2 of water.

Indigo, it has been already mentioned, is not soluble in water, but it may be rendered so by the action of different re-agents; and hence its use, along with these, in dyeing. To get it in solution, it is put into water with green vitriol and lime, or with sulphuret of arsenic and potashes, and after being boiled for some time, a green fluid is produced, which, however, becomes blue by ex-

posure to air, and gradually deposits indigo of its original colour.

The change effected on indigo by the substances employed, seems to be the abstraction of oxigen, which has been removed, in the one case by the protoxid of iron, liberated from the green vitriol by the lime; in the other, by the hydro-sulphuret formed by the action of the alkali on the arsenical compound. That this is the case, appears to be proved by the experiments of Dalton, who found, that by exposure of the solution to air, oxigen, amounting to about 1-8th of the weight of the indigo, was absorbed. Cloth, also, when dyed in the indigo liquor, is green, but gradually becomes blue when hung in air, the oxigen of which is abstracted. If, on the contrary, indigo be mixed with per-sulphate of iron and lime, it is not dissolved.

Another method of getting indigo in solution, is to mix it with bran, or other vegetable substances, and allow it to ferment; but this method is not much practised.

According to Liebeg, indigo contains a peculiar principle, to which he has given the name of *indigogene*. It may be procured by digesting it with green vitriol and lime, in vessels containing hydrogen, so as to exclude the air, by which a yellowish-coloured fluid is formed, and which, when drawn off from the impurities, keeping it all the time from contact of air, deposits a white precipitate on the addition of muriatic acid.

Indigogene, though white as thus procured, is kept with great difficulty in this state, unless it is quite dry. If the least moisture be present, it absorbs oxigen rapidly from the air, and becomes blue. When put into water in open vessels, it is gradually converted to blue, so that in both instances indigo is re-produced, (An. de Ch. xxxv.)

These experiments of Liebeg still farther confirm the opinion, that the changes effected on indigo in the process of dyeing, are the abstraction of part, or the whole of its oxigen, but which it regains on exposure to air.

Logwood, (Hæmatoxylon Campechianum.)

Logwood, when boiled in water, affords a solution of a dark brown colour, but is altered by the addition of other bodies. A few drops of acid change it to yellow. The alkalies, on the contrary, make it purplish. On the addition of a solution of alum, the colouring matter combines with the earth of the latter, so that, if any substance be added by which the earth is precipitated, it takes the other along with it. That this is the case, is shewn by throwing a solution of alum into the infusion, and then putting in some potashes; the earth and colouring matter are deposited, leaving the fluid colourless.

Some of the metallic salts act powerfully on logwood. Thus, green vitriol changes it to black, and a solution of tin in muriatic acid makes it bright red; hence the use of logwood in the preparation of black and red ink, as already described, (p. 201. 38.)

Logwood contains a peculiar principle, discovered by Chevreuil, (An. de Ch. lxxxi.) to which he has given the name of *hæmatin*. It is obtained by digesting the wood in water at 130, filtering and evaporating to dryness. The residue is then dissolved in alcohol, and the solution evaporated a little, after which it is mixed with water, and again concentrated by evaporation. When the liquid cools, minute crystals are deposited.

Hæmatin, thus procured, is of a reddish colour, having an astringent bitter taste. It is soluble in warm water, forming an orange red solution, which becomes yellow as it cools, but the original colour is restored by again applying heat. Acids added to the solution at first change it to yellow, but gradually make it red. Alkalies make it assume a purple tinge; but if used to excess, they first change it to violet, then brown, and lastly yellow; an effect produced also by the soluble earths. Metallic salts alter its appearance, those of iron striking a deep blue, and of tin a rich red colour.

Saffron.

Saffron, the dried pistils of the *crocus sativus*, is supposed also to contain a peculiar principle, which Bouillon La Grange, and Vogel, have called *polychroite*, from the different colours which it affords, (An. de Ch. lxxx.) It is obtained by evaporating the watery solution to dryness, dissolving the residue in alcohol, and again evaporating.

Polychroite is of a yellowish colour, and deliquescent. It is soluble in water and in alcohol, the solution losing its colour by exposure to air, and which cannot by any means be recalled. It is also destroyed by chlorine.

Nitric acid, added to the solution, changes it to green, and sulphuric acid to blue. Some of the metallic salts throw down precipitates; sulphate of iron, for instance, affords one of a dark brown, and nitrate of mercury one of a red colour.

Arnotta, or Annotta.

Arnotta, or annotta, is another colouring matter much used in dyeing. It is prepared from the seeds of the *Bixa Orelana*, a native of the West Indies. For this purpose, after the husks are removed, they are put into troughs with water, and beat till the whole of the colouring matter is taken from them. The fluid is then heated, the scum, as it collects on the surface, being removed, after which it is boiled down to the proper consistence, and dried.

The solution of annotta is yellowish, and, like other colouring matters, is changed by different substances. Thus, the alkalies make it much darker; and from the solution, acids throw down an orange-coloured precipitate.

It is employed principally in dyeing silks yellow or orange; for which purpose, it is always mixed with an alkali, as potashes, to render it more soluble in water.

It is also used for colouring cheese, being dissolved in the milk before it is curdled.

Litmus, or Archill.

Litmus is a substance prepared from different kinds of lichens, but principally from the *L. rocella.* For this the plants, after being dried, and reduced to powder, are mixed with lime and urine, and allowed to ferment, by which a reddish substance is formed, that soon changes to blue. It is then again mixed with lime, and dried by exposure to air. Instead of drying it, it is often kept fluid till required.

The solution of archill is purplish, being changed to red by acids, and to blue by alkalies; and hence its value as a test. It is used chiefly in dyeing silks and ribbons, but the colour is not permanent.

Madder.

Madder is another substance employed abundantly as a dye. It is the root of the *rubia tinctorium,* cultivated chiefly in Holland, and imported to this country in powder. When dissolved in water, it gives a solution of an orange red colour, which becomes brighter by the addition of potashes, but is changed to yellow by acids. When mixed with alum and potass, the whole of the colouring matter is thrown down; and hence one method of preparing *lake.* For this purpose, two ounces of madder are treated with successive portions of water, till the whole of the soluble matter is extracted; and having boiled the fluid, a solution of an ounce of alum is thrown in, and immediately afterwards an ounce and a half of a saturated solution of carbonate of potass. The powder precipitated, after being well washed, is dried by the cautious application of heat.

Metallic solutions also change the appearance of madder; green vitriol makes it a clear brown, and sugar of lead brownish red.

Quercitron.

Quercitron, the inner bark of the *quercus nigra*, a native of North America, is another substance much used by dyers. The infusion is of a yellowish brown colour, which is darkened by alkalies, and made lighter by acids. Alum throws down the colouring matter of a deep yellow; muriate of tin forms a lively yellow; and sulphate of iron a dark yellow precipitate.

Turmeric.

Turmeric, the root of the *curcuma longa*, cultivated in the East Indies, is a yellow powder, having a pleasant odour, and an aromatic bitter taste. It is partly soluble in water, affording a yellow solution, which is easily changed to brown by alkalies; and hence its use as a test. It is but sparingly soluble in alcohol, to which it gives a red colour. Turmeric is the principal ingredient in *Curry Powder*, and it is used also in dyeing.

Cochineal.

Cochineal is a red dye, derived from the animal kingdom. It is the female of a small insect, a native of Mexico, which feeds on the leaves of the *cactus opuntia*, and from which it is supposed to derive its colour. After being collected from the plants, they are plunged into boiling water to kill them, and dried in sunshine. The infusion is crimson, and is changed to reddish yellow by acids. Alum makes it become red, but at the same time causes precipitation, and on this depends the mode of preparing *carmine*. This is procured by throwing one pound of cochineal, previously ground to powder, into 10 gallons of water, and boiling it about three hours, after which three ounces of carbonate of soda and half an ounce of alum are added, and the whole well stirred. Having remained at rest for some time, the clear fluid is

drawn off, and mixed with the white of two eggs, and again boiled. A coagulum is formed, which, when the ebullition ceases, soon falls to the bottom. The clear fluid is poured off, the residue thrown on a filter, well washed, and dried.

Red lake is prepared, by boiling the fluid from which carmine has been procured, along with potashes and the precipitate formed on the first addition of alum. The clear fluid is then drawn off, alum is again added, and a precipitate is thrown down, which, when washed and dried, is lake, (Rees' Encyc.)

Cochineal, though affording a crimson solution, is generally used for dyeing scarlet; for which purpose, it is mixed with super-tartrate of potass, the colour being fixed by a salt of tin.

Dyeing.

The art of dyeing consists in fixing colours on cloth, so that they shall not be destroyed by exposure to air, or by washing. The articles of which cloth is composed, have an attraction for colouring matter, but it varies in different instances. In some it is so powerful, that the colour may be applied without any preparation, except merely scouring to remove impurities, which is usually done with a weak solution of potashes. After this, it is soaked in the infusion of the dye-stuff, which adheres to it, imparting its colour, and which cannot be removed by washing. In other cases, on the contrary, the attraction is so weak, that though the colour can be imparted to the cloth, it is not permanent; but when this is the case, it may be fixed by the use of a third substance, which has an attraction for both. Thus, if cloth be dyed by madder, it acquires a reddish colour, which may, however, in a great measure be removed; but if it be previously soaked in a solution of alum, then dried, and afterwards put into the madder vat, it is dyed, and the colour is fixed, owing to the attraction of the alumina for the cloth, and also for the

dye, by which they combine, and are thus kept in union with it. This constitutes a difference in the process of dyeing, and has given rise to the division of dye-stuffs into two classes, the *substantive* and *adjective*, attaching to these words the same meaning as in common language. A substantive colour is therefore one that will act *of itself*, an adjective colour requires *the addition of some other body*. Those substances used along with adjective dyes have been called *mordants*, from the idea that they *bite in* the colour; they are chiefly alum, and some of the metallic salts, particularly those of tin, occasionally also of mercury, lead, and iron. But these, besides fixing the dye, also change its appearance; and hence their use in procuring different colours from the same dye-stuff, as the remarks on the properties of colouring matters shew, these being changed by the addition of the different agents mentioned.

From what has now been said, it is evident that there are two modes of dyeing; either by substantive or adjective colours. When the attraction between the cloth and the colour is strong, all that is necessary, is to soak it in the infusion of the dye-stuff, by which the colour is imparted, and fixed; but when weak, it must be first saturated with a mordant, and then with the colouring matter. Of course, the former must vary according to the nature of the dye.

There is still another method altogether different from those mentioned; it is not by using the dye already prepared, but by combining the cloth with substances which act on each other, and strike the colour required; and in this way also the colouring matter becomes fixed. Thus, cloth can be dyed black, by soaking it in a mixture of infusion of nutgalls and green vitriol, but it is not permanent. If, however, it be previously immersed in the infusion, and after being dried, be put into the solution of the salt, the black is produced, the same chemical action taking place on the cloth, as when the solutions themselves were mixed, and it is thus rendered fixed. In this

way, a great variety of colours may be produced, many of which have been already noticed when describing the properties of the metals and of colouring matter. In dyeing the compound colours, as green, this is generally done by making the cloth blue, and afterwards soaking it in a yellow infusion. Thus, by dyeing it with indigo, and afterwards putting it into an alum bath, and then into quercitron, the yellow of the last, and the blue of the first, produce the green.

As mordants are used to fix colour on cloth, it is evident, that if, instead of being applied to the whole, certain parts only are covered, the colour, though communicated to the whole, will be fixed *only on those parts saturated with the mordant;* and that this is the case is easily shewn, by making some traces with infusion of nutgalls on cloth, and allowing it to dry, and then putting it into solution of green vitriol; the colour, on the traces only, will be durable. Hence the mode of applying a pattern on a white or coloured ground, which is called *calico printing.*

Two mordants are in general use by calico-printers, —acetate of alumina, and acetate, citrate, or tartrate of iron; the former prepared by mixing sugar of lead with alum, by which sulphate of lead is precipitated, and acetate of alumina held in solution; the latter, by dissolving the metal in the acids.

The solutions thus formed are made of the requisite consistence with starch, to which in general a little Brazil wood is added, to give it colour, that the traces may be seen when applied to the cloth. The instrument by which this is done, is a block of wood, on which the pattern is cut. In some places, it is interlaid with the felt of hat, which takes up a great deal of the mordant when necessary; and for some of the nicer patterns, copper is sometimes used, by which the impression is more delicate. The block being covered with the mordant, is applied to the cloth, and struck with a mallet, or forced down by machinery, to cause it to leave on as much as possible; and by applying it repeatedly, the whole web

is properly covered, and after being dried in a stove room, to fix it, is put into the dye-vat, by which the colour is imparted to the whole; but by boiling it in bran and water, and exposing it on the ground, only those parts previously covered with the mordant are coloured, so that the pattern is dyed on it.

By applying different mordants to the same web, different-coloured patterns may be produced. Thus, if part of a piece of calico be covered with the aluminous mordant, another with the iron, a third with a mixture of these, and the rest left untouched;—when put into a madder-vat, the first will become red, the second black, the third purple, chocolate, or lilac, according to the proportions, and that part uncovered will be reddish, but which, on keeping it in bran a little fermented, and then exposing it on the field, disappears, leaving the ground white.

Connected with the art of dyeing is that by which *bandanas* are made. For this purpose, a web is dyed Turkey red, and after being laid up in folds, is placed between metallic plates, in which are cut patterns, similar to that to be given to the cloth. Through the holes thus cut in the plates, a solution of the bleaching compound (vol. i. p. 450.) is allowed to flow, by which the colour of the exposed part of the cloth is discharged, and a white pattern is left on the red ground.

For fuller information on this subject, the reader is referred to Bancroft on Permanent Colours; Berthollet's Elemens de l'Art de la Teinture; Henry, Manchester Mem. iii.; Thenard et Roard, An. de Chem. lxxiv.; Aikin's Chem. Dictionary.

PART V.

ELECTRICITY AND GALVANISM.

SECTION I.

ELECTRICITY.

As the subject of electricity properly belongs to Mechanical Philosophy, it is not to be supposed that the circumstances concerning it are to be detailed at length. All that is meant is, to state as much as will enable the reader to trace the connexion between it and other agents, and to point out the means of producing the chemical changes it occasions.

When certain bodies are rubbed against each other, for instance, amber or glass upon woollen cloth, small sparks dart from them, and they quickly acquire the property of drawing light objects towards them, which are almost instantly repelled. All bodies do not possess this property. If, instead of amber or glass, a metal be employed, little or no effect is produced. The substance first discovered to draw light objects to itself is amber, the ἤλεκτρον of the Greeks, and hence the origin of the word *electricity*. Many others have since been found to possess the same quality, as glass, jet, sulphur, wax, resin, silk, fur, and worsted. These are called *electrics*, be-

cause, when rubbed, they excite electricity. Those, on the contrary, which have not this property, that is, those which do not attract light objects when rubbed, are called *non-electrics;* they are metals, water, and a number of salts and earths.

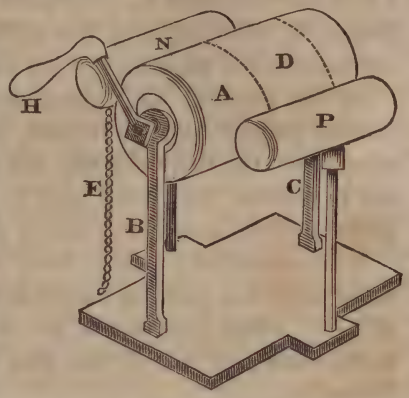
If, when an electric is rubbed and electricity excited, a non-electric be brought near it, the electricity is carried off; if, however, an electric be approached, it is not taken away, but allowed to accumulate. The former, non-electrics, are therefore said to *conduct* it, and hence the division of bodies into *conductors* and *non-conductors.* Electrics, it has been said, do not conduct, while non-electrics conduct; *electrics* are therefore *non-conductors,* and *non-electrics* are *conductors.*

Though bodies have been divided into electrics and non-electrics, it must not be supposed that the latter have no power whatever of exciting electricity. Though a piece of metal, for instance, when held in the hand, and rubbed on woollen cloth, does not draw light objects towards it, yet it can be made to acquire this power, as when it is insulated, that is, fixed to a glass handle, and then rubbed with fur; and the same occurs with other bodies belonging to the class of non-electrics, so that all objects can, by certain means, be made to excite electricity; but the difficulty with which some do it, has given rise to the division. This want of power, in some bodies, to show signs of electric excitation, can be easily accounted for. If we suppose that this agent exists in all objects, and becomes sensible by friction, the less quickly the excited body conducts it, the more powerfully will it retain it, and of course the more easily can it be made to shew it; whereas, when the object is a good conductor, almost the instant it is evolved, it will be conveyed away. Hence, though becoming sensible when a metal is rubbed, yet, as the metal conducts it with amazing rapidity, it is with great difficulty it can be detected.

The same remarks are applicable to conductors and non-conductors, this division being by no means a natural one; for those belonging to the latter class do con-

duct it, though extremely slowly, indeed so much so, that when thrown into them, it is allowed to accumulate.

To excite electricity, an electric is rubbed either against another electric or a non-electric. The common instrument for this purpose, is the electrical machine, which consists of a glass cylinder, A, which is an electric, made to rub against a non-electric, as a metal placed on a cushion of leather *. The cylinder is supported on non-conductors, as glass rods B C, and is therefore said to be *insulated;* and at each side there is placed a metallic cylinder P N, to convey the electricity, and hence called the *conductors*, the latter having a cushion between it and the cylinder, on which the metallic matter is placed. These are also supported on non-conductors, that the electricity may not be carried off. To the glass cylinder is fixed a handle H.



Luckily for the science of electricity, air is a non-conductor; had it been otherwise, it would be carried off the moment it is excited. Moist air, however, and all objects, whether conductors or non-conductors, become conductors when moist; hence it is that during rain, or in crowded rooms, electrical experiments do not succeed, the air and apparatus being rendered so damp, that the moment the electricity is excited, it is carried off; and hence also the necessity of having the machine, and all the apparatus, well warmed, that they may not condense the moisture, and thus become conductors.

If the electric subjected to friction be completely insulated, as is the case with the glass cylinder of the ma-

* The metallic matter employed is an amalgam of mercury, and zinc or tin, and is placed on the cushion with a little grease.

chine, the electricity is at first weak, and very soon ceases; but if a communication by means of a conductor be made between it and the earth, or some other object, it becomes stronger, and the supply may be kept up as long as the friction is continued, but it ceases when the communication is broken. The machine has therefore a metallic chain E, suspended from the cushion's conductor N, and touching the table, so that it may be in communication with some other object.

By the machine thus constructed, electricity may be excited proportionate to its size, and the state of the atmosphere; the drier the air, the stronger it is. When put in motion, electricity may be got from it, as by approaching the knuckle to one of the conductors.

When electricity passes from one substance to another, there is a peculiar odour, a slight noise, and a flash of light, which is bright if the experiment be performed in the dark; so that it thus flies off from the conductor in sparks.

In vacuo it passes off without interruption, dispersing itself in beautiful luminous clouds or streams.

That a communication between the machine and the earth, or some other object, is necessary for keeping up the supply of electricity, is shewn by removing the chain of communication E; it is at first weak, and soon ceases; but on again applying it, it becomes strong.

The most remarkable property of electrified bodies, is their first attracting, and then repelling light objects. Thus, if a small cork ball, suspended by a thread, be brought near one of the conductors P, it is attracted, and then repelled. It is, however, no sooner repelled, than it is again attracted, again to be driven off. In the first instance it receives a supply of electricity, by which it is repelled by the conductor, and gives it off to the surrounding air. On being again attracted, it receives another, which it as quickly disperses through the air around it.

On this depends the power of causing light bodies to dance. Thus, if a common tumbler be held over the wire of the conductor, so as to throw electricity into it,

and it be placed over some small pieces of the pith of elder tree, they are attracted and repelled, so that they are kept constantly in motion. On the same principle, if a piece of metal leaf, placed on a plate of metal, be held near the conductor, it is kept suspended between them, or rather it moves upwards and downwards, being alternately attracted and repelled.

Substances electrified by being approached to or connected with the conductor P, repel each other. If, for instance, a person lay hold of one of the conductors, and stand on an electric stool, which is merely a board supported on glass feet, or non-conductors, by which it is insulated, he becomes electrified, the electricity passing from the machine into his body; and his hair will *stand on end*, because each hair, being electrified, repels the one adjoining it. The same happens if we attach a bunch of feathers to one of the conductors; they are electrified, and repel one another, and the different parts of the same feather also repel the others.

All of these phenomena are produced, whether we make use of the conductor P, or that connected with the cushion N, bodies being attracted and repelled by it; and if two or more be electrified, they also repel one another, so that it may be considered a general law, that *bodies similarly electrified repel each other.* If, however, bodies be electrified at the different conductors, instead of repelling, they attract one another; and that this is the case, is easily shewn. Having fixed a wire to P and to N, a little curved, and the points approaching, suspend from each a piece of pith, and then put the machine in motion, they instantly fly together, and continue so as long as the excitation of electricity is kept up. *Hence bodies differently electrified attract each other.*

Since bodies similarly electrified repel, and those in opposite states attract each other, we have an easy means of ascertaining, not only when a body is in a state of excitation, but also the kind of electricity; for by electrifying positively a cork ball, suspended by a silk thread, and bringing another body in an excited state near it, it will attract it if negatively, and repel it if positively elec-

trified. Perhaps the most delicate *electrometer*, is that recommended by Bennet. It consists of two slips of gold leaf, of about 2 inches in length, suspended in a bottle, from a piece of wood used as a stopper. The leaves instantly diverge, when brought in contact with an electrified object, so that in this way electricity, though in trifling quantity, may be discovered.

The repulsion of light objects also furnishes a means of measuring the quantity of electricity. In Bennet's electrometer, the more the leaves diverge, the more powerful it is. The instrument generally used for this purpose, is Henley's quadrant electrometer, which consists of a pillar of wood AB, terminating below in a piece of brass, by which it may be fixed to the conductor of the machine. To the upper part of the pillar, a graduated semi-circular plate, C, is fixed, to the centre of which a moveable index DE is attached, formed of a wooden rod, with a cork ball at its extremity. When the electrometer is connected with the conductor, and the machine put in motion, the index is moved; the angle which it makes, and which is measured by the scale, being according to the intensity of the electricity.



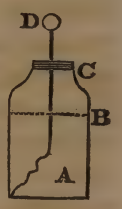
Dufay was the first who drew the attention of philosophers to this fact, that bodies repel or attract each other, according to the part of the machine at which they are electrified; and from it he was led to suppose, that there are two kinds of electricity, one given out by glass, and therefore called *vitreous*, the other from resinous bodies, and therefore termed *resinous*. Substances, however, according to circumstances, excite different states; thus, glass may be made to give out what is called the resinous, while the vitreous can be got from resins. This induced Franklin to doubt the accuracy of Dufay's theory, and to propose one much more simple, and which, in this country at least, is generally received. He supposed that there is but one agent producing these effects, which is a fluid possessed of high elasticity, repelling its own particles, but having an attraction for all other kinds of matter. He imagined that it exists in all bodies, but in

very different quantities. Some have equal shares of it, some have a superabundance, others a deficiency. Hence, when two, each having its own share, are rubbed together, he imagined that the equilibrium is disturbed, that one gained, while the other lost it; the former he said became *plus*, the other *minus* electrified. Instead of these terms, we often speak of a body being *positively* and *negatively* electrified, the former corresponding with the plus, the latter with the minus condition. The plus and positive state of electricity are synonymous with the vitreous of Dufay, and the minus or negative with the resinous. When, then, the machine is revolved, the electricity is supposed to be taken by the glass A, from the metallic matter on which it rubs, N, and is given to the conductor P; and as there is a chain suspended from the rubber N, and communicating with the table, the supply is kept up, there being a constant flow towards the rubber, from it to the cylinder, and from it to the conductor. Hence it is that the conductors have also got different names. That connected with the chain N, and from which the electricity is supposed to be taken, is called the *negative*, the other, P, into which it passes, is termed *positive*, the former losing, the latter having an overcharge of it. From the positive conductor, it flies off to the surrounding objects with different velocities, according to its surface. If it be terminated by a point, as when a wire is fixed to any part of it, it passes off in an uninterrupted stream, as is shewn by approaching the knuckle to the wire; but if terminated by a knob, it darts off in sparks. Thus, when the knuckle is brought near the ball, it receives sparks more or less bright, according to circumstances.

The same remarks apply to bodies *receiving* electricity, pointed ones taking it in more quickly than blunt ones. Thus, if the knuckle be approached to the conductor, it receives sparks, but on presenting a wire at the distance of a few inches, the sparks cease, the electricity flying into the wire. On withdrawing it, sparks again appear, but on again approaching it, they disappear. Hence the part of the positive conductor P, next the cylinder, has a number of wires terminated by points, and presented to

the glass, that the electricity, when excited, may be drawn off quickly.

Though the electricity thus excited may be greater at one time than another, according to the size of the machine, and the state of the weather, when we wish it to be very powerful, we must have recourse to means of collecting it. The apparatus used for this purpose, is the invention of Muschenbroeck, and is called a *Leyden jar*. It is merely a glass jar or bottle, A, coated with tin-foil both inside and outside to the same height B. Through the wooden stopper C, there passes a wire terminated by a knob at D, and touching the foil in the interior. When the ball D of the jar is approached to the positive conductor, the electricity flies into it, but it does not escape to the surrounding atmosphere, or the table on which it is standing; on the contrary, it is accumulated, so that the inner surface becomes highly positively electrified, and the outer one in a corresponding negative state; and that it is so, is shewn by making a communication between the interior and exterior coating, by which the equilibrium is restored. For this purpose a *discharger* is used, which is merely a brass wire terminated at each end by a ball X Y, and fixed at the middle to a glass handle Z. Having charged the jar by keeping its knob for some time near the positive conductor, the ball X is to be applied to the tinfoil, and Y to the knob D, and the electricity is instantly set free with a spark, which is much brighter than that got from the machine. The jar may be discharged in other ways than by the discharger. Thus, having charged it, if a person hold it in one hand, and apply the other to the knob, the electricity is evolved, and produces, when small, a peculiar sensation in the fingers and elbows, but, when large, and fully charged, it passes through the chest; if a number of them be employed, forming what is called an electric battery, it may be made so strong, as to knock the person down, or even to kill him.





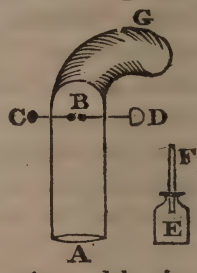
When electricity passes from one body to another, it travels with immense velocity, and is accompanied with great heat. When a *Leyden jar* is discharged, the electricity travels along its wire, and that of the discharger. It might be expected, that as the discharger is lengthened, it would require a longer time to pass along it; this is not, however, the case, at least we are not aware of any difference. Thus, if the communication be made by means of a chain, fixed to the walls of a room, and at each corner be connected with a bladder, full of an explosive mixture of oxigen and hydrogen, when the jar is discharged by it, the whole of the bladders are exploded at the *same instant*, even though many feet separate.

In several experiments made by the Members of the Royal Society, it was found that the electricity from a Leyden jar, passed through a chain of several miles in length, apparently as quickly as along the common discharger, at least there was no perceptible difference. Though this is the case, yet it does not travel with equal celerity along all bodies. According to Cavendish, iron conveys it 400 millions of times more quickly than water, and even water itself has its conducting power changed, by dissolving different substances in it. (Ph. Tr. 1776.)

The discharge of the jar is also accompanied with heat, which is often so intense, as to set fire to bodies. If, for instance, cotton besmeared with powder of resin, has a spark passed through it, it is kindled, provided the machine is in good condition. For this purpose, the cotton is placed on a metal stand, the bottom of which is attached to a chain; the jar being charged, is also put on the chain, and the discharger is then applied, the one ball to that of the jar, the other to the cotton; the moment that the electricity is discharged, that is, when the spark passes from the discharger to the metal on which the cotton is placed, the resin is kindled.

The discharge of electricity is sufficient also to cause gases to explode. When hydrogen and oxigen are mixed, and heat is applied, there is an immediate explosion,

and the same is the case if an electric spark be passed through them. For exploding the gases, a strong glass tube is used, having a wire passing in at each side, and terminating in the interior at the distance of the 1-10th part of an inch from each other, as in the experiment with the bladders. On this depends the *electrical pistol*, which is merely a glass tube, open at A, and shut at B, with its wires C D. To fill this with an explosive mixture, it is held over a bottle E, containing 1 of iron filings, 4 of water, and 1 of sulphuric acid, by which hydrogen is set off. By holding it a certain time over the tube, hydrogen enters, displacing part of the air; a cork is then put in at A, and having charged a Leyden jar, it is put on a chain, one end of which is connected with the wire D, and holding the pistol by G, in the hand, C is then to be applied to the knob, by which the electricity flies from the one to the other, and as there is a spark passing from wire to wire in the tube, it explodes the gases.



Though electricity thus excites sufficient heat to produce combustion, yet, in passing along a body, it does not warm it. Thus the wire of the discharger, by which a jar is discharged, is not heated in the smallest degree. In an experiment related by Van Marum, the bulb of a delicate thermometer was made part of the chain of communication, but it did not indicate the slightest rise of temperature. It is only where the electricity passes from one object to another, that it produces its heating effects; thus, in the discharge of the jar, the spark is observed where the ball of the discharger touches, or rather approaches that of the other. In the same way, in the experiment with cotton and resin, the knob of the discharger is made to touch that on which the inflammable is placed, a spark passes from one to the other, and the heat is there evolved sufficient to excite combustion.

After these few preliminary observations, we have now to state the effects of electricity, and the uses to

which it is applied in a chemical point of view.—Most of the changes produced on bodies by this wonderful agent, seem to depend, in a great measure, on the high temperature it induces. The heat excited, it has been already mentioned, is sufficient to inflame resin. By some of the very large electrical machines, many inches of metallic wire have been fused; even quartz, one of the least fusible of minerals, has been melted by it. The greater the resistance offered to its passage, the greater, in general, is the caloric evolved.

The points of fusion of different bodies, seem to vary from those occasioned by heat, as has been shewn by Van Marum, particularly with respect to metals; but this is probably owing to their different powers of conducting electricity.

Electricity occasions remarkable changes on gaseous bodies,—causing the union of some, and the decomposition of others. The apparatus employed for the transmission of electricity through gases, is of the same construction as the electrical pistol; merely a strong tube having wires passing into it, and terminating at the distance of about 1-10th of an inch from each other, (vol. i. p. 202.) The jar, after being mounted on a mercurial trough, has the gas introduced, and an electric spark passed through it, in the manner already described in the experiment with the pistol.

From this property of electricity, it proves an excellent means of analysis, because, by the transmission of sparks through gases, some are made to enter into union, and are probably condensed, while others, if compound, have their ingredients separated; so that by marking the condensation or enlargement, the composition of the substances may be discovered. The particular changes occasioned, and the method of applying electricity in analysis, have been given when describing the properties of the bodies that have been subjected to its action, and of those that are used with it, (vol. i. p. 202.) Electricity accelerates evaporation. It invigorates the growth of plants, and proves a stimulus to the animal frame, as in

cases of palsy, and in suspended animation. In applying it for these purposes, the part of the body to be subjected to its influence, is merely made part of the chain of communication, by which a Leyden jar is discharged. Thus, in passing it through the arm, the jar being charged, is held in the hand and applied to the shoulder. If to be passed through the leg, a chain being tied around the thigh, is connected with the jar, which is then to be charged, and by applying the knob to any part of the foot, the electricity is transmitted through the extremity, which is thus made a part of the chain of communication. A much more easy method of electrifying, particularly when to be applied generally to the body, is to make the person stand on an electrical stool, and take hold of the conductor. As he is insulated, the electricity passing from the machine into him does not fly off, it is accumulated; but it may be withdrawn from any part, by another approaching a metallic rod, fixed in a glass handle.

It is a curious fact, that many animals have the power of giving an electric shock at pleasure. The most remarkable of these is the Gymnotus Electricus of South America; but a more familiar one is the Torpedo, which occurs on the shores of the Mediterranean, and also on the coast of Britain. Though these exist in a fluid, which is a conductor, yet it is remarkable that the electricity is not carried off from them; and that they have a supply of it, is shewn by touching them, by which they give a shock sufficient even to kill a small animal.

Electricity is also evolved during certain changes which bodies undergo. When vapour is condensed, the objects in contact with it shew signs of electricity; and sulphur, and many others, when passing from fluid to solid, also emit it. It is even evolved by mere pressure. From a series of experiments, Becquerel concludes, that all substances assume different electric states by pressure. Thus, two which are good conductors, have their electric equilibrium disturbed the moment that the pressure is removed; but, if one be a bad con-

ductor, the effect continues for some time. He has also found that heat modifies the developement of electricity in these cases. From these experiments he has concluded, that the light emitted by powerful concussion, is due to the electricity evolved on the surface at the moment of compression, and hence probably the cause of the light during the discharge of an air gun, from the abrasion of the particles of foreign matter carried in with the wadding, (vol. i. p. 172.) In many instances electricity is discharged during a separation of particles, and the cause is probably the same as in those just mentioned. Thus, when sugar is broken, or cloth torn, in the dark, there are flashes of electric light; and the same also happens on drawing off a flannel jacket, or a silk stocking, electricity being evolved by the mere separation from the body with which they were in contact.

Electricity is likewise evolved during many of the occurrences of nature. The aqueous vapour which arises from the surface of the earth, as it is condensed, forms clouds, which become electrified, and the earth being in an opposite state, if they approach, an electric spark passes between them. Electricity also often flies from one cloud to another, the one having been positively, the other negatively electrified. This is the cause of lightning, and the vibration produced in the air occasions thunder, which is more or less loud according to the quantity of electricity, and the distance at which it is heard. Dr Franklin made the important discovery, that the electricity thus discharged in the heavens, is the same as that given out by an electrical machine; which he proved by a very simple experiment. He elevated into the air a silk kite, from which there descended a cord containing a metallic wire, attached to a conductor, supported on a glass rod. By this he was enabled to charge a Leyden jar, which, when discharged, produced the same effects as common electricity.

Perhaps the most useful application of our knowledge of the laws of electricity, is the means which it has pointed out of protecting buildings and ships from being de-

stroyed by lightning, which consists in erecting what are called *conductors*. These are merely copper or iron rods, the thickness depending on the size of the building, fixed to the outer walls, reaching to a certain height above the highest point, and descending into the earth a little below its foundation, and terminating in a pool of water. It has been found that a conductor will protect from lightning a circular space, the diameter of which is four times the length of the rod itself, measured from the highest point of the object to which it is fixed. Its height ought therefore to be, taking it from the highest part of the building, rather more than a fourth of the diameter of the building itself.

It has been already mentioned, that pointed bodies receive electricity much more easily than blunt ones. Conductors ought therefore to be terminated by a number of points, that they may draw towards them the electricity which is discharged from the clouds, and a metal ought also to be used that is not liable to be affected by the weather; hence they are generally made of copper. In fixing a conductor, it is necessary to use a substance that is a non-conductor, otherwise, instead of defending, it would be the means of destroying the building, by transmitting the electricity through it. For this purpose, it is attached to iron staples, but covered with cloth and pitch, to make them non-conductors. Conductors should always be made to take the shortest course from the top to the bottom of the building, and all the parts of the roof covered with metal should be attached to it by means of rods, that the lightning may be carried off from them. Ships are also protected by rods or plates passing from above the top-mast, along the mast, the lower end passing through the keel into the water.

SECTION II.

GALVANISM.

It has been already mentioned, that electricity is excited by friction, as with an electrical machine, in which the glass cylinder, rubbing against the cushion with its metallic matter, is supposed to deprive the latter of it. It may, however, be evolved by other means; but when this is done, the phenomena presented by its action, vary from those of common electricity.

The wife of Galvani, professor of anatomy at Bologna, accidentally discovered, that when the nerve of the limb of a frog, lying near an electrical machine, was touched with a piece of metal, it was thrown into violent convulsions, even though it had been dead for some time. This discovery, made in the absence of Galvani, when communicated to him, naturally excited his curiosity. He repeated the experiment, and after varying it in different ways, proved satisfactorily what had thus been discovered by mere accident. He found that the convulsions could also be excited independent of the electric machine; for having, with the view of proving the truth of some of his opinions with respect to muscular motion, suspended a frog by means of a metallic hook on an iron railing, he found that at certain times they were excited. When also the nerve of the extremity was covered with a metallic leaf, and the leg laid on another piece, on establishing a communication between them by means of wire, they became stronger.

These experiments of Galvani are easily performed. Having deprived the lower extremities of a frog of the skin, the great nerves passing near the spine are to be laid bare by cutting off a piece of the vertebral canal. A slip of tinfoil is placed around the nerves, and a communication made by means of silver wire between the tin and any part of the leg, and the convulsions are excited.

They may also be induced, and much more easily, by suspending the denuded extremities, with the tinfoil on the nerve, on a rod of metal, and then by bringing the foil and the rod in contact, as by squeezing them between the finger and thumb, the legs are instantly convulsed; but the convulsions cease when the metals are separated.

Galvani found that the convulsions are excited even though only one metal is employed, as by establishing a connexion between the tinfoil on the nerve and a part of the leg, by taking hold of the former by one hand, and the other by the other. When, on the contrary, still keeping hold of the tinfoil, the leg is touched by a glass rod held in the other hand, there are no convulsions.

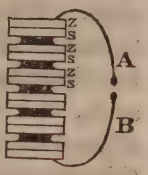
From the different experiments which Galvani performed, he was inclined to suppose that the action was the same as takes place in electrical animals, and that the metal, or metals, served merely as conductors. He conceived that the different parts of the body were in the *plus* and *minus* states of electricity; and that on making a communication between them, it was discharged, and caused the convulsions. Hence he gave it the name of *animal electricity*.

Volta and others have, however, given a different view of the subject. He supposed that it was merely common electricity evolved by the metals, the animal being the conductor, and shewing its effects. He has shewn, for instance, that particular sensations are excited in the human body by a similar adjustment. If we take two pieces of metals, say zinc and silver, apply one above, the other beneath the tongue, no particular sensation is excited; but if they be made to touch each other, a peculiar metallic taste is perceptible. When, also, we put the zinc between the upper lip and gum, and the silver between the under lip and gum, and bring them together, a flash of light darts across the eyes, provided the experiment be performed in the dark.

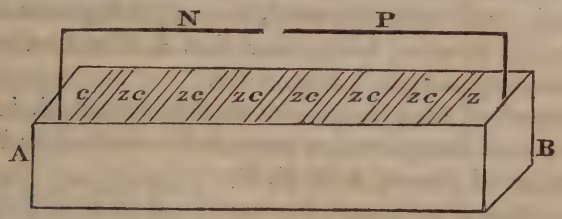
Though these different facts seemed to prove that the effects produced on animals by metals were merely those of common electricity, this opinion was for a consider-

able time opposed, till, by a particular contrivance, it was put beyond the possibility of doubt.

It occurred to Volta, (Ph. Tr. 1800,) that the convulsions might be greater by using more pieces of metal. He accordingly took a number of plates of zinc and silver, and arranged them in pairs, putting moist card between each pair, and following the same order throughout, as zinc, silver card; zinc, silver card, &c. &c. When the legs were touched by means of wires AB, the effects were much greater than when only two pieces were used; and he also found, that they were invariably in proportion to the number, fully proving the truth of his opinion, that the electricity was given out by the metals, and not by the animal. It has therefore been called *galvanism*, from its discoverer, and sometimes also *voltaic electricity*, and the apparatus by which this was proved is now termed a *voltaic pile.*



Several improvements have been made on the pile, the most important of which was the discovery of Cruickshanks. The apparatus used by him consists of a wooden trough, A B, in the sides of which, are cut grooves,



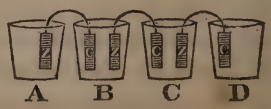
at about the distance of $\frac{1}{4}$ or $\frac{1}{2}$ of an inch from each other according to its size, and into which are placed a plate of copper and zinc C Z, soldered together, following the same arrangement as in the construction of the pile, copper, zinc, copper, zinc, &c. so that, in looking from one end B, along the battery, we observe all the zinc faces, and from the other, A, all the copper ones.

It is not a matter of indifference what metals we employ, in constructing a battery; they must possess different powers of oxidation, or of being acted on by acids.

One must be easily affected, while the more the other resists their action, the better. For the former, zinc is generally used; could gold or silver be had sufficiently cheap, they would answer well for the latter; but their expense prevents their use. Copper, which is comparatively cheap, and not easily acted on, is generally preferred.

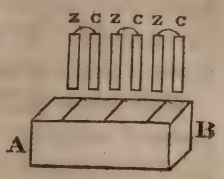
Different liquids are used for the excitation of galvanism. When water is employed, the effect is trifling. Solutions of the compound salts produce more effect; but those by which the greatest action is excited, are the acids, and of these nitric is preferred. It is generally diluted with about 20 or 30 parts of water. Instead of this, muriatic acid, with 16 of water, may be used; and for some purposes, a mixture of nitrous and sulphuric acid is employed. Mr Children recommends a mixture of 3 of nitrous, and 1 of sulphuric, diluted with 30 of water. When we wish the galvanism to be strong, we rather use a large battery, than increase the strength of the acid; because, in the latter case, it acts powerfully on the plates, and destroys them; and as it would be inconvenient to have a great many plates into one trough, several small ones are used, the adjoining ends being connected by wire, taking care that a zinc termination is always opposed to a copper one.

Instead of the arrangement already described, it has been found that galvanism may also be excited by filling a number of glasses, A, B, C, D, with diluted acid, and placing into each a plate of zinc and copper, Z, C, not in contact,



but connecting the adjoining pieces of the different vessels by wire, following the same arrangement throughout, of zinc copper, zinc copper, &c. the zinc of one vessel being joined to the copper of the adjacent one. This apparatus was proposed by Volta, and called by him, the *couronne de tasses*. Though not so easily managed as the common trough, yet, owing to both sides of the metal being exposed to the acid, the action is

more powerful. The form in which it is now used, is a wooden trough with glass partitions, or an earthen-ware one, A B, divided into compartments, into which the acid is poured, and the plates Z C, joined by a cross bar D, at the top, are inserted, so that the copper of one pair, and the zinc of another, are in the same compartment.



These plates are easily removed and cleaned, and for this purpose they are generally suspended to cross beams, and put into the acid when required.

Another, and still more powerful form of battery, is that recommended by Wollaston. It consists in placing into each cell a zinc plate with a copper one on each side, the latter being connected at top and at bottom by metallic arcs, and kept supported on the former by pieces of wood; the zinc plate of one cell being connected with the copper of the adjoining one by a metallic arc, as in the *couronnes de tasses*. By this contrivance the power is increased by one half.

By the troughs thus constructed, the action can be kept up much longer than in the pile; the effects are greater from the same extent of surface, and they are more easily managed, and sooner in action.

That the effects are greater by this, than by using only two metals, may be easily shewn. Having suspended the frog on the wire connected with one end of the trough, N, touch it with another from the opposite end, P, and the convulsions are much stronger than in those instances already mentioned.

The sensations excited by the battery are very peculiar. If a ball be placed at each end, and the hands, after being wetted, are put on them, there is a thrilling in the fingers and arms, which becomes painful if it be large; at the same time convulsions are excited. It is necessary, however, for the success of this experiment, that the hands be wet, and the greater the extent of moistened surface, the more powerful are the effects. If,

also, we increase the conducting power of the fluid, we render them still stronger. Acids are good conductors; hence they ought to be washed with much diluted acid, as muriatic. If they be applied when dry to the balls, there is little effect.

Galvanism passes through bodies with different degrees of celerity. Good conductors of electricity are good conductors of galvanism, and those which do not conduct the former, are non-conductors of the latter. Of course glass, and dry vegetable matter, are non-conductors. All fluids, charcoal, and metals, are conductors, the last being by far the best.

When the opposite ends of the battery are made to communicate by means of a conductor, the effects are astonishing; of course they differ according to the substances by which the communication is established. If a wire from each end N P, be brought into contact, there is a spark more or less vivid, according to the size of the apparatus and the strength of the acid, and which is renewed each time they are brought together. If, instead of using a good conductor as a metal, we employ one of inferior conducting power, as charcoal, the effects are still more brilliant. Thus, if the wires be terminated by charcoal, and these are brought into contact, the light is very intense, indeed so much so, as to be painful to the eyes. For this experiment, the charcoal ought to be prepared from willow; and for this purpose, pieces of the wood, of about an inch in length, and 1-4th of an inch in thickness, and tapering to a point, after being imbedded in sand, are kept at a full red heat for two hours. When cold, they are to be tied by fine wire to those used as conductors from the opposite ends of the trough.

Sir H. Davy found, on using the very powerful battery of the Royal Institution, consisting of 2000 pair of plates, each nearly 6 inches square, that when the pieces of charcoal were kept at the distance of four inches, there was a brilliant arch of light, and the greater part of them was constantly in a state of ignition.

This may be produced even under water, for if the

pieces of charcoal be placed in a tumbler of it, they emit a spark each time they are brought into contact, but by no means so brilliant as in air.

By galvanism, there is not only the evolution of light, but what is still more remarkable, metals are easily ignited, and even fused, so that an intense heat is also excited.

When the metallic conductors N P, are placed at the ends of the trough, and a communication established between them, by means of very fine wire, as platinum, it is made red hot, the length ignited depending on the strength of the battery. If a metallic leaf be employed, the heat is sufficient to convert it into vapour. This is done by putting the leaf on one of the wires of the trough N, and having the other terminated by a zinc plate. The moment that the plate is made to touch the leaf, the latter is dissipated in vapour, being consumed with a bright light. Brass leaf burns with a white flame, and red streaks are observed running along its surface. Even gold and silver are consumed by it, the former burning with a white, the latter with a green flame.

By the large battery of Mr Children, which consisted of 20 pairs of plates, 6 feet by 2 feet 8 inches, a platinum wire 1-30th of an inch in thickness, and 18 inches long, became at first red hot, and then fused. In another experiment, a bar of the same metal 1-6th of an inch square, and 2 inches long, was also made red hot, and even fused at the extremity, (Ph. Tr. 1815.)

Though in these cases, the extent of surface of metal in the battery was very great, and the expense considerable, Dr Wollaston was able by a small plate of zinc to ignite platinum wire; in fact, the apparatus which he used, was merely a silver thimble, the sides being squeezed together, and a piece of zinc, 3-4ths of an inch square placed between them. By this, when immersed in a mixture of 1 of sulphuric acid, and 50 of water, platinum wire 1-3000th of an inch in thickness, and from 1-50th to 1-30th of an inch in length, was easily fused, (An. of Ph. vi.)

The heat excited by galvanism, is sufficient also to fuse the most refractory earths. If, for instance, any of these be placed on the metallic conductors, or, which is still better, if they be kept between the pieces of charcoal, by which the wires are terminated, the moment that they are brought near each other, the earth is softened, and even in some cases actually melted.

Dr Hare of Pennsylvania, who employed a very large apparatus, with copper on each side of the zinc, has shewn the astonishing powers of galvanism in igniting charcoal, and fusing metals, (An. of Ph. xx.) When 250 zinc plates were used, platina wire 3-16ths of an inch in thickness was fused, and made to flow like water, and iron of the same dimensions burned with explosive violence. When pieces of charcoal were brought into contact, and then withdrawn, a most intense ignition took place, and the point of the positive piece, shot out in the direction of the longer axis, and increased in length to about 1-10th of an inch; while the negative piece underwent a change precisely the reverse, it was shortened, and a crater-like cavity supplied the place of the point. On reversing the position of the pieces, making the positive negative, and the negative positive, the cavity was very soon filled, and the lengthened point of the other disappeared, and in the course of time, a cavity similar to that originally on the other was formed. From these experiments, it appears that there was actually a transfer of charcoal from one to the other, the direction being invariably from negative to positive. On examining the charcoal, specks of fused matter were observed, from which it was at first supposed, that the inflammable matter had really been liquefied, but it has been now ascertained, that this was occasioned by impurities.

The chemical changes which galvanism effects, are also very striking.

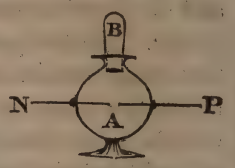
Soon after the construction of the voltaic pile, Nicholson and Carlisle discovered that its ends were in opposite states of electricity. The zinc, or most oxidable termination, exhibiting the plus or positive, the copper or less

oxidable, being in the minus or negative state. This has given rise to the distinction of the ends of the trough, and of the wires coming from them, into *positive* and *negative*. By the positive wire, then, is to be understood that from the zinc or most oxidable metal, and which exhibits the plus or positive electricity; by the negative wire is meant that from the copper, or least oxidable end, and which is in the minus or negative state.

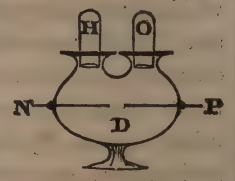
Galvanism is a most powerful agent in causing decomposition. By increasing the strength of the battery, substances held together by the most powerful affinity, are easily separated. We have thus been enabled to ascertain the composition of some, till then reckoned simple, and new bodies have also by its aid been discovered, which have themselves proved powerful means of analysis. Nicholson and Carlisle first pointed out its effects on water, and drew the attention of others to the subject. Since then, it has been successively examined as a chemical agent, by Volta, Fourcroy, Thenard, Berzelius, and others, on the continent; and in this country, by Cruickshank, Wollaston, and Davy. About the beginning of this century, Sir H. Davy, at that time professor at the Royal Institution of London, subjected a number of substances to the action of a powerful battery, by which he discovered the compound nature of many, and illustrated by numerous instances, the chemical changes produced by this wonderful agent.

Nicholson and Carlisle, it has been already said, first pointed out the effects of galvanism on water. For this purpose, they put into it brass wires from the opposite ends of the pile, and the moment the communication was established, a stream of gas was observed to rise from the wire, connected with the silver extremity, and which they found to be hydrogen; at the same time the other seemed to have undergone oxidation. On using wires not liable to be oxidated, gas was given off from each, one of which as before was hydrogen; the other, that set free from the wire, coming from the zinc end of the pile, was oxigen; hence the conclusion was natural, that

the water was resolved into its component parts. This experiment is shewn most satisfactorily, by using a vessel of the form A B. On the introduction of the wires N P, the gases are disengaged, and collected in the tube B. That it is a mixture of oxigen and hydrogen, is proved by removing the tube when full, and applying flame; there is an immediate explosion.

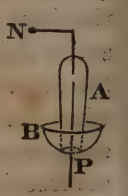


In these experiments, there is not only the decomposition of the water, but the gases are given off invariably at different wires; and that they are so, is shewn by using a globular with a tube over each wire, so that the gas from each can be collected, and its quality ascertained. On putting in the wires, the tubes H O soon become filled; that in O, over the positive wire P, is oxigen; and that it is so, is proved by removing it, and putting a piece of recently extinguished wood into it, which is instantly kindled; that in H, over the negative wire N, is hydrogen, as is shewn by its inflammability. In this instance, there is collected twice as much gas in H as in O, water being a compound of two of hydrogen, and one of oxigen.



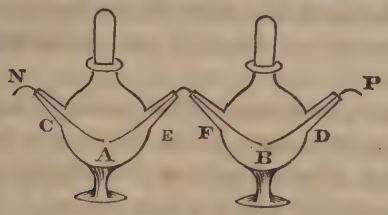
It is from this circumstance that the wires have by some been called *oxigen giving*, and *hydrogen giving*; terms, however, not much employed.

Nicholson and Carlisle not only proved the decomposition of water by galvanism, they also, by using a different form of apparatus, first effected the separation, and afterwards the re-union of its ingredients. For this they used a glass tube A, through the shut end of which there passed a wire N. Being filled with water, it was inverted on a cup B, through which also there was passed a wire P, of such length, that when the tube was placed over it, the wires came near to each other. The moment that the communication was established



from the ends of the pile, by connecting the conductors with N and P, the gases were given off, and rising to the top, caused a depression of the water; but when this came so far down as to leave the upper end of the wire P exposed, a spark passed from it to N, and caused the gases to enter into union, by which the tube again became full.

In carrying on the decomposition of water, it is not necessary that the wires be inserted into the same vessel; different ones may be employed, provided they are connected by a moistened fibre, or cotton. Thus, if two vessels, A B, have the wires inserted into them, N at C, and



P at D, a piece of cotton being put in at E F, the gases are disengaged, that from P being oxigen, and from N hydrogen.

If, instead of connecting the vessels by cotton, a wire be used, there is the disengagement of gas, not only from N P, but also from the intermediate one, and, like the others, it has also its negative and positive extremities. Thus, if N be inserted into A, and P into B, and a wire, E F, be used as a means of communication, N will give off hydrogen, and P oxigen; but besides this, there is also oxigen coming off from E, and hydrogen from F.

In the experiments stated, gold or platinum wires must be employed, or, which answers equally well, copper ones, terminated by two or three inches of platinum. If copper be used, there is the disengagement of only one gas; and to prove this, we have merely to insert them into the globular A, a gas is given off from N, and which, on the application of flame, will be found to burn slowly away, shewing it to be hydrogen. The wire P, if exa-

mined, will be seen covered with a brownish crust, which is oxid of copper.

In decomposing water by galvanism, the nearer the wires are to each other, but *without being in contact*, the greater is the evolution of gas, and the effect depends more on the *number* than the *size* of the plates. In this respect there is a difference from the action on metals. The larger the plates, the more brilliant is the combustion of the leaf. The decomposition of the water depends also on its purity. If pure, it goes on slowly, but if it hold in solution any salt, as glauber or sea salt, it takes place much more rapidly. If the wires be brought into contact in the fluid, there is no decomposition, the galvanism passing on through the metal without interruption.

In the first experiments which were performed on the decomposition of water, it was uniformly found that a little acid was collected around the positive, and alkali around the negative wire; which gave rise to numerous speculations with respect to the nature of the galvanic agent, and of the gases formed during the decomposition. It was, however, proved by Davy, that in these cases the acid and alkali arose from impurities in the water, or from the action of the air; for he found, by carrying on the decomposition *in vacuo*, and in gold cups, that there was no other change than the formation of oxigen and hydrogen.

Acids are also easily decomposed by galvanism. If the wires from the battery be put into concentrated sulphuric or phosphoric acid, the inflammable bases are collected around the negative one, while oxigen, the other ingredient, is set free at the positive.

It has been already mentioned, when describing the properties of the fixed alkalies, that it was by the aid of galvanism that Sir H. Davy proved their compound nature, and discovered their metalloid bases. Hisinger and Berzelius, in a paper published in 1803, (Gehlen's Journ. de Chem.) had shewn, that on subjecting different substances to the action of galvanism, oxi-

gen and acids had a tendency to arrange themselves around the positive wire, while inflammables and salifiable bases collected around the negative; which was afterwards satisfactorily proved also by Davy.

The consideration of these facts led to the opinion, that the affinities of bodies might depend on their electrical conditions, and consequently, that by changing these, their affinities might also be altered, and the ingredients of which they are composed drawn asunder. In 1806, he was induced to try the action of galvanism on the alkalies, by which he not only discovered their composition, but happily confirmed the truth of his speculations with respect to the mode of action of this powerful agent. (Ph. Tr.)

In subjecting potassa to the galvanic influence, a small piece, made a conductor by exposure to air, so as to become moist, was placed on a platinum cup connected with the negative wire. The moment the communication was completed, by touching it with the positive one, it began to fuse at the points of contact, at the same time there was a violent effervescence on the surface, and at those parts next the cup, minute globules, having a high metallic lustre, appeared, some of which burned, while others became covered with a white crust. In his first attempts, he did not succeed in collecting the metallic matter, owing to its being inflamed; but he afterwards discovered, that by carrying on the action under the distilled oil of naphtha, the combustion was prevented, and he was thus enabled to procure a sufficient quantity to ascertain some of its properties. He found that the effervescence was occasioned by the disengagement of oxigen. The metallic globules, when heated in air and in oxigen, were inflamed, oxigen was consumed, and potassa was generated. He therefore concluded, that he had succeeded in decomposing the alkali, and proved it to be a compound of oxigen and the metallic matter, to which he gave the name of potassium.

Similar experiments were performed with soda, and the same results obtained, the soda disengaging oxigen, and

yielding a metallic matter, which was at once inferred to be its base.

We cannot expose ammonia, in its pure state, to the action of galvanism; we must therefore have recourse to one of its salts, and it is necessary also to call in the aid of mercury. For this purpose, a small piece of sal ammoniac, with a cavity in it, is placed on the platinum cup, and after pouring in a globule of mercury, and touching it with water, the communication is established, by which the mercury is instantly enlarged, its fluidity is gradually impaired, and it at last becomes of the consistence of butter. The amalgam, thus formed, has a metallic appearance, and effervesces when thrown into water, giving off hydrogen and ammonia. By mere exposure to air, ammonia is evolved, and it returns to the state of mercury.

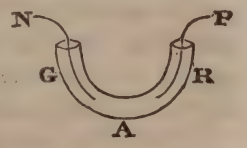
Different conjectures have been thrown out concerning the nature of this substance. Berzelius and Davy supposed, that ammonia being analogous in its composition to the fixed alkalies, may be a compound of oxigen and a metallic base, which, by its union with different proportions of oxigen, generates hydrogen and nitrogen, the component parts of ammonia. The amalgam was therefore imagined to be a compound of the base and mercury; consequently, when thrown into water, it was supposed that the oxigen united with the base, to form ammonia, while the hydrogen was set free; and again, on exposure to air, a similar change took place, oxigen being derived either from it or from the moisture. Gay Lussac and Thenard have, however, given a different view of the subject. They have supposed that it is a compound of mercury, nitrogen, and hydrogen, the latter being in larger proportion than exists in ammonia; consequently, when thrown into water, the ammonia is dissolved, and the hydrogen set free. *(See Ammonia.)*

It has been already mentioned, that when water, holding a salt in solution, is subjected to galvanism, besides the evolution of oxigen and hydrogen, an acid collects around the positive, and an alkali around the negative wire. This decomposition of the neutral salts was first

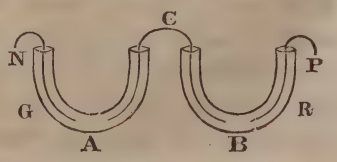
observed by Cruickshanks, and afterwards by Hisinger and Berzelius; but we are indebted principally to Davy for the very important facts disclosed concerning the agency of galvanism on this class of substances. Generally speaking, the action is the same in all. The changes, therefore, that always occur, will be first mentioned, after which, those peculiar to any particular salt will be noticed.

When the wires are introduced into a solution of a salt, suppose sulphate of soda, the first thing observed is the decomposition of the water; but on leaving them in for some time, the component parts of the salt itself are actually drawn asunder; and what is very remarkable, the acid and alkali are collected around the different wires. In every instance, the acid appears at the positive, and the alkali at the negative one.

The action of galvanism on compound salts is easily shewn, and for this, no great size of battery is required. If a bent tube A, be filled with solution of glauber salt, tinged blue by cabbage water, and the wires introduced at P and N, the water is at first decomposed, as is shewn by the disengagement of gas, but the salt itself also very soon undergoes decomposition; the colour of the infusion in R becomes red, shewing that it contains acid, that of G becomes green, shewing that it has an alkali. So that the ingredients of the salt are separated, and collected around the wires in the opposite limbs of the tube, the acid being with the positive, the alkali with the negative one.



In the above experiment, the decomposition is carried on in one vessel. It may, however, be effected though several be used; but the results vary according as they are connected. If two or more syphons be employed, A B, and the adjoining limbs, be connected by moist cotton C, on the introduction of the wires N P, the decomposition commences; the infusion in R

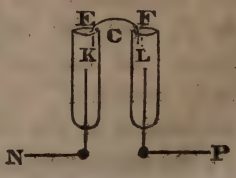


becomes red, shewing that it contains acid; that in G is green, shewing that it has alkali. The colour of the intermediate limbs is not altered. If, however, instead of cotton, a wire be used as the connecting medium, the infusion into which it is placed is also changed, so that there is alternately red, green, red, green, and this may be carried on in any number of tubes, the positive wire, and the corresponding ends of the connecting ones, always collecting the acid around them; the negative wire, and the corresponding ends of the other, always drawing towards them the alkali.

The wires have not only the power of drawing the acid and alkali around them, they can actually cause them to migrate from one part of the apparatus to another. Thus, if the wires be removed from the tube A, and reversed, that is, P put into G, and N into R, the infusion will very soon change its appearance; that which was red will become green, and the other which was green will become red, shewing that the acid has passed from R to G, and the alkali from G to R, having crossed each other at A.

If the other apparatus be employed, and the wires as before reversed, the same will happen, the two limbs which were red will become green, and those which were green will become red, so that the acid and alkali in each syphon must have crossed one another at the bending.

In all of the above experiments, though the decomposition has been carried on in different vessels, yet the acid and alkali have only taken different parts of the same; the decomposition may, however, be so conducted as to cause a migration from one to another, perhaps one of the most remarkable circumstances pointed out concerning the action of galvanism on the salts. Thus, if two tubes E F, with wires K L passing through them, be filled with the solution tinged blue, and a communication made between them by a piece of cotton C, the moment the wires P N from the battery are



connected with the others, the decomposition commences; the solution in F will become red, and that in E green; the whole of the acid, therefore, from E, must have passed along the cotton into F, and the alkali from F must have gone into E. So that the ingredients are collected in separate vessels; and if the experiment be carried on sufficiently long, not the smallest particle of acid can be detected in E, nor of alkali in F.

In the experiment just mentioned, it is necessary to use a moistened fibre as the connecting medium, and that it is so, is proved by using wire instead of cotton; there is no change whatever in the colour of the infusion, shewing that there is no migration.

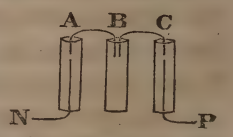
If, besides the two vessels, other intermediate ones be employed, the decomposition is effected, provided, of course, cotton or any other moist body be used to connect them. Thus, if between E and F a third tube be placed, all of them filled with the tinged solution, and a piece of cotton be carried from E to the intermediate one, and another from it to F, on attaching the wires, the decomposition begins, and if the experiment be continued for some time, acid is collected in F, and alkali in E, but the colour of the intermediate tube is not changed. In this instance, the whole of the acid from E must have passed through the intermediate tube into F, while the alkali from F must have gone through it into E; and hence it is that there is no change in the colour of the infusion, because the salt in E and F, undergoing decomposition at the same time, the acid from the one, and the alkali from the other, meet in it just in neutralising proportions.

There is still another very remarkable circumstance to be noticed. The wires of the battery not only cause the acid and alkali to migrate from one part to another; but their powers of attraction are so strong, that they can cause them to pass through bodies apparently impermeable to them. Thus, if the bottom of the syphon A (p. 389.) be stuffed with cork, or with tow, so tight as to present a perfect barrier to the transmission of water,

and if a solution of salt be put in G, and blue cabbage water into R, on the introduction of the wires, the infusion will very soon become red, or if the solution be put into R, and the cabbage water into G, the latter will become green; so that, in this experiment, the acid or the alkali must have been drawn with such force, as to pass through a substance which, before it was subjected to the galvanic influence, it could not permeate.

What has been said of the alkaline, applies also to the earthy and metallic salts, all of these, when subjected to the galvanic influence, being decomposed, the acid being collected at the positive, and the base at the negative wire. The same migration of the ingredients may also be occasioned, the acid and base being easily driven from one vessel to another.

Though the action of galvanism on compound salts is, in general, the same in all, yet the phenomena vary according to the nature of the substance employed, depending, in a great measure, on the solubility or insolubility of the ingredients, and their powers of affinity for other bodies. If, for instance, three tubes, A B C, be employed, A being filled with a solution of sulphate of soda, and B C with cabbage infusion,



after connecting them by cotton, and adjusting the wires, the decomposition commences, the acid will pass from A through B into C, while the alkali will remain in A. If, however, instead of water, a solution of baryta be put into B, the acid, during its passage through it, unites with the earth, and as it forms an insoluble compound, it falls to the bottom, and being thus withdrawn from the sphere of action, is retained there, so that it does not pass on to C. This, however, is the case only when the compound formed is insoluble; if a base be employed, with which the acid will form a soluble salt, it is not retained by it. Thus, on using ammonia instead of baryta, the acid flows on to C, as when pure water is used.

If, instead of a salt, both of the ingredients of which

are soluble, we employ one, the base of which is insoluble, or nearly so, it is stopped in its passage through B. Thus, let solution of sulphate of magnesia be put into C, the acid is retained in it, while the magnesia flows along the cotton to B, but falling to the bottom, gets out of the sphere of action, and remains there. If a metallic salt be employed, the phenomena are still more remarkable. Thus, if solution of nitrate of silver be put into C, the acid remains in it, while the oxid flows along the cotton; but as its ingredients are easily separated, it is decomposed, the oxigen is attracted by the positive wire, while the silver is deposited in its metallic state, and gives the cotton a resplendent surface.

It is remarkable also, that when the salts are under the influence of galvanism, their ingredients are, to a certain extent, deprived of some of their properties. Thus, if a saline solution be put into A, and cabbage infusion into B and C, the acid, as it passes through B into C, does not change the colour of the former; or if the alkali be made to migrate by putting the solution into C, on flowing through B, it does not make the infusion green; the change of colour is not effected till they reach their places of destination.

The phenomena may be still farther varied; we may have the appearance of acid or base as we choose. Thus, if the syphon tube A, (p. 389.) be filled with saline solution tinged blue, and the positive wire be put into R, but instead of the negative into G, a piece of moist cotton be employed, the decomposition is slowly accomplished, but the colour of the positive limb only is changed. If, on the contrary, the negative wire be put into G, and the cotton into R, the infusion in the former will become green; but there is no change in the latter. A circumstance still more remarkable has also been noticed. If, instead of cotton, our own body be used as the connecting medium, placing the finger of one hand into the tube, and that of the other into the fluid in the battery, acid or alkali will shew itself, according to the wire we em-

ploy; if the positive, the limb R becomes red, if the negative, G becomes green.

The preceding remarks apply to the action of galvanism on soluble salts. The same changes, however, may, by particular management, be produced on insoluble compounds; for even these cannot withstand its power of effecting decomposition. Sulphate of baryta, sulphate of strontia, and others, when made a part of the circuit, give off their acid to the positive, and their base to the negative wire.

The more compound bodies, as rocks, also yield their ingredients to them. Thus, bazalt and zeolite are easily decomposed, and the alkali they contain collected around the negative wire. Animal and vegetable substances also, when subjected to its influence, are deprived of their acids and bases; and what seems very strange, without having their vitality destroyed.

From what has now been said, it may be laid down as a general law, *that oxigen, chlorine, iodine, and acids, are drawn towards the positive, hydrogen, inflammables, alkalies, earths, and metallic oxids, around the negative wire.*

Having stated the different facts concerning galvanism, we have now to notice the opinions entertained with respect to its nature and development, and the manner in which it acts so as to produce the changes mentioned.

It has been already stated, that it is generally admitted that galvanism and electricity are one and the same agent; and that they are so, is evident from their effects. They both cause contraction of the animal fibre. In passing from one object to another, both emit light and heat. Conductors of electricity are conductors of galvanism, while those which do not conduct the one, are non-conductors of the other. In the pile or trough, the opposite ends are in different states, corresponding to the positive and negative conductors of an electric machine, and by a battery a Leyden jar may be charged.

Dr Wollaston has also shewn, that by immersing wires from the conductors of a machine into a solution of sulphate of copper, a precipitate was collected around the negative pole, and on reversing the current of electricity, that is, making the negative wire positive, and the positive negative, the precipitate was re-dissolved, and afterwards appeared round the other wire. For the success of this experiment the wires must be coated with wax, except at the point; or, which answers still better, they may be included in glass tubes, but so as to leave the extremities projecting. When, also, wires thus armed were put into pure water, and a succession of sparks transmitted through it, a current of gas arose, owing to the decomposition of the fluid.

Sir H. Davy, by a similar adjustment, obtained analogous results. On passing electric sparks from the wires, through solution of sulphate of potassa, the whole of the acid in the course of time collected around the positive, and the whole of the alkali around the negative one.

Allowing that electricity and galvanism are the same, a question naturally arises, How does it happen that they act so differently? In answer to this, it is supposed, that as given out by a common machine, or by a battery, it differs with respect to *intensity* and *quantity*. It is supposed, that when evolved by the former, it is in a state of high intensity, but in no great quantity, whereas, when given out by the latter, the quantity is great, but the intensity low.

As the intensity of the electricity from the machine is great, its velocity is supposed also to be more rapid; and hence it is that it passes more easily through air, and other non-conductors, which, when excited by galvanic arrangements, it cannot traverse. It is in this way, also, that it is supposed we may account for the difference in the effects produced, by the increase of the electricity, when excited by these means. Thus, if a certain quantity from a battery ignite an inch of wire, double the quantity will ignite double the length, and the igni-

tion can be kept up for some time; but by increasing that from a machine in the same ratio, a much greater length of wire is made incandescent, and the effect is quickly over.

With respect to the means by which electricity is evolved in galvanic arrangements, two opinions have been entertained; the one suggested by Volta, the other deduced from the researches of Fabroni.

Volta maintained, that in the pile, electricity is disengaged by the *mere contact of the metals;* the electric equilibrium being disturbed, one gained, while the other lost it, the former shewing positive, the latter negative signs.

He was induced to hold this opinion, from the fact which he had previously ascertained, that if two pieces of different metals, zinc and silver, insulated by being fixed to glass rods, be brought into contact, and then separated, the former becomes positively, and the latter negatively electrified. He afterwards proved, that other metals possessed the same property, though in different degrees. Other bodies also, as charcoal and plumbago, have shewn similar powers, and Davy has proved, that if a dry earth, and a dry acid, be brought into contact, and then separated, the former is in the positive, and the latter in the negative condition.

So far these facts agree with the explanation given by Volta, of the excitation of electricity in galvanic arrangements, the fluids between each pair of plates acting merely as conductors. Thus, suppose the first pair of plates composed of copper and zinc, (See Battery, p. 377.) the latter robs the other of part of its electricity, which it immediately communicates to the fluid, which in its turn conveys it to the next plate of copper, and so on through the whole series, and hence it is, that the copper end is negative, and the zinc positive.

It is from this idea, also, that he has called the metals *electro-motors*, and the action electro-motion, a term used by Sir H. Davy.

Volta allows, that there is a great difference in the

power of the pile, according to the nature of the fluid, but this, he asserts, is owing to their conducting differently. Water conducts slowly, saline solutions more powerfully, but the best conductors are the acids ; and hence it is, according to him, that when they are employed, the galvanic action is most energetic. The variety in the power of the different metals in exciting galvanism, he supposes, is owing to the ease with which one takes it from another, being in some cases greater than in others. Thus, zinc acquires it from all the rest, while gold yields it to any other, so that, were the battery constructed of these, it would, *ceteris paribus*, be more powerful than when made of any others.

The other explanation ascribes the excitation of electricity *to the chemical action between the fluid and the metals*, by which they probably suffer a diminution in capacity. Thus, suppose the trough consisting of diluted acid, with a plate of zinc and of copper on each side of it, the fluid in the first compartment acts on the zinc, communicating oxigen to it, by which electricity is evolved, and the metal thus becomes negative. The electricity taken from it, passes through the fluid to the next plate, which is copper, and on which there is little or no chemical action to excite electricity, so that it merely receives from the fluid, that taken from the first, and instantly communicates it to the piece on its opposite side. The same is supposed to go on in each succeeding compartment ; the quantity of electricity, therefore, increases as it proceeds through the series of plates, so that the last must have accumulated in it all that taken from the others, and hence it is, that it is in a highly positive condition, while the opposite end is proportionally negative ; the greater the number of pairs, therefore, the greater the difference between the different extremities. (See Wollaston's Papers, Ph. Tr. 1801.)

Though the explanation of Volta at first sight seems plausible, yet it does not stand the test of experiment. It has been proved by Davy and others, that the greater the chemical action, the more powerful is the galva-

nism; hence, if a diluted acid, as sulphuric, be used, by which the action is more violent than when concentrated, the battery is in more powerful action. Now, according to Volta, the reverse should be expected, because strong acids are better conductors than weak ones. Besides, as the action proceeds, by which it is gradually becoming weaker and weaker, the galvanism also becomes more and more feeble, till it at last entirely ceases. It has also been proved by the most satisfactory experiments, that when a trough filled with pure water is kept *in vacuo*, there is no galvanic action; while in oxigen it is more powerful than in air, and in hydrogen or carburetted hydrogen it also ceases. All of these facts not only militate against the theory of Volta, but clearly shew a connexion between the excitation of the electricity and the chemical action; at the same time, however, it must be admitted, that they do not prove that it is the sole, or even the primary cause in its evolution. This has induced Davy to maintain, that both the contact of the metals and the chemical action are concerned, the electricity being first evolved by the former, and its supply kept up indirectly by the latter, by its restoring the electric equilibrium. Thus, when the plates of zinc and copper are put together, each of the former becomes positive, and of the latter negative, and the fluid acting as a conductor, the whole of the evolved electricity is accumulated at the positive end, while the opposite one is in a corresponding negative condition; but to keep up the supply, the metals must be again brought to their former state, and this he conceives is accomplished by the chemical action, for the electro-negatives of the fluid in each compartment, such as the oxigen and acid, pass to the zinc, and the electro-positives, as the hydrogen and bases, to the copper, by which each regains what it had lost; but this is no sooner effected, than the equilibrium is again disturbed, because the contact is continued, electricity is evolved by each pair, and, as before, conveyed by the fluid to the positive pole. The more powerful the action, therefore, the more quickly the metals regain their original conditions, and hence

it is, that the effects are to a certain extent in proportion to it.

Taking it for granted, that the chemical action is the sole cause of the disengagement of electricity, Dr Bostock has endeavoured to explain the mode of action, and account for its transfer from one end of the battery to the other. He supposes that the electric fluid has an attraction for hydrogen, that as the acid acts on the first plate of zinc, oxigen is given off, and electricity disengaged, which, combining with the hydrogen also set free at the same time, is carried to the next plate, the copper, by which they are separated; the copper seizing the electricity, disengages the hydrogen, which flies off in the state of gas. The same action goes on in the second compartment, with this difference, that the electricity given out by the second zinc plate is greater, by the quantity which it received from the first; that from the third gives out its own, and that got from the preceding pairs, so that, as already mentioned, all the electricities are accumulated in the last piece; consequently the greater the series, the greater the difference between the opposite ends, and of course the effects more powerful.

With respect to the manner in which galvanism acts in effecting decomposition, and causing the evolution of different bodies at the different wires, it has been already mentioned, that substances, by mere contact, assumed opposite electric conditions; and it has been proved by the experiments of Davy and others, that by touching metals with substances which have a tendency to enter into union, they acquired different states of electricity, according to the nature of the substance with which they were brought in contact. Acids communicated to the metal a positive, and bases a negative condition, by which, of course, the acids themselves became negative, and the base positive. Other bodies, it was found, acted in the same way; thus oxigen is itself a negative, and hydrogen and other inflammables a positive. From this it is evident, that substances may be divided into two

classes, electro-positives and electro-negatives, and as these are constantly subject to the laws of electric attraction and repulsion, they must, when united, and then brought under the influence of electrified objects, be separated, and occupy different situations, according to their electric condition. Electro-positives will be repelled by positive, and attracted by negative bodies, while electro-negatives will be repelled by negatives, and attracted by positive ones, and hence, when subjected to the galvanic action, the former will collect around the negative, and the latter around the positive wires.

We can thus easily account for the changes produced by the agency of galvanism. Thus, in the examples given, water containing oxigen an electro-negative, and hydrogen an electro-positive, when subjected to it, has its ingredients separated, the oxigen is repelled by the negative, and attracted by the positive wire, while, on the other hand, the hydrogen is repelled by the positive, but attracted by the negative; the former is therefore given off from the positive, and the latter from the negative wire. In the case of saline solutions, the acids are electro-negatives, and the bases electro-positives, consequently the former appear at the positive, and the latter at the negative pole.

By subjecting compounds to the action of powerful galvanic arrangements, it has thus been ascertained to which of the wires their ingredients are drawn, and thus, also, the class to which they belong has been discovered. From the experiments which have been performed, it has been observed, that all bodies which have a chemical attraction for each other have different electric conditions. Here, however, a question naturally arises. How does it happen that bodies of the *same* class combine? It is well known that sulphur, carbon, phosphorus, unite with metals, and even metals with one another, though they all belong to the same class. To this, however, a satisfactory answer can be given. Though all objects may be divided into two classes, yet those in the same class are, to a certain extent, in opposite conditions when compar-

ed with each other. Thus, in the following table of electro-positives, each body would give electricity to any one below it; they must therefore be in opposite states with respect to each other,

silver,
copper,
iron,
lead,
zinc.

It is from this circumstance that Davy has actually thrown out the conjecture, that electric and chemical attraction may depend on the same primary cause. "Electrical effects," he says, "are exhibited by the same bodies when acting as masses, which produce chemical phenomena when acting by their particles. It is not, therefore, improbable, that the primary cause of both may be the same, and that the same arrangements of matter, or the same attractive powers which place bodies in the relation of positive and negative, *i. e.* which render them attractive of each other electrically, and capable of communicating attractive powers to other matter, may likewise render their particles attractive, and enable them to combine when they have full freedom of motion."

It has been already mentioned, that the effects produced by galvanic batteries differ materially according to the number and size of the plates; a different law, however, is followed in each case. The ignition and fusion of metals depend on their size; the larger the plates, the greater is the length of wire ignited. Thus, if a pair of a foot square be used, the effect is considerable; but if these be cut so as to make plates of only 3 square inches, and constructed into a battery, the action on the wire will be trifling. On the contrary, the power of decomposing depends on the number; the plates, when of a square foot, produce but little effect, while a battery made of these cut into smaller pieces, easily decomposes water and compound salts.

This is supposed to be owing to a difference in the *intensity* and *quantity* of the galvanism. Thus, in a

battery with a number of plates, it has to pass through a great many portions of fluid which are not good conductors; its velocity is therefore retarded, it becomes accumulated, and consequently its intensity increased. When applied to water or saline solutions, it meets with the same resistance, and is in a great measure retained, and is thus supposed to act more powerfully in decomposing them. In a battery of a few large plates, on the contrary, it has to pass through few portions of fluid, and is therefore more quickly transmitted. The wire also which is subjected to its influence is itself a good conductor, and conveys it with rapidity. Unless, therefore, a large supply is afforded, the ignition will not take place; ignition and fusion, then, depend not so much on the intensity as on the quantity.

It is evident that some law must exist with regard to the relation that number and size bear to each other. According to Davy, the power of producing decomposition increases very nearly as the squares of the number; that of ignition seems to augment even in a greater ratio, for 20 plates, each two square feet, did not ignite 1-16th as much wire as the same number having each eight square feet, the acid being of the same strength in both.

After what has been already said with respect to the decomposing powers of galvanism, it is unnecessary to make any remarks with regard to its utility in this point of view. It is evident that a valuable means of analysis has been placed within our reach, and one which seems capable of overcoming the most powerful attractions. Galvanism has been employed in the cure of diseases, as palsy, rheumatism, deafness, involuntary contraction of the muscles, asthma, and some others, and it has been recommended in cases of suspended animation. The method of applying it is very simple. The part to be subjected to its influence is wetted with a solution of salt, or with very much diluted muriatic acid, and having tied a ball to each wire, they are to be applied at the same time to the moistened skin, the person holding them having on gloves, to prevent the transmission of the

electricity through his body. In many respects galvanism is preferable to electricity. The apparatus is less liable to injury; besides, we are altogether independent of the state of the weather, which is often a bar to the use of an electric machine.

Some interesting experiments have been lately performed, with the view of ascertaining the effects of galvanism in calculous complaints. Urinary calculi are various in their composition. One kind is composed almost entirely of a peculiar acid called uric, while others contain the acids and earths which usually exist in urine, such as phosphate of lime, phosphate of magnesia and ammonia, and oxalate of lime, and it is on these last that the trials have been made.

Prevost and Dumas (An. de Ch. xxiii.) found, that when a phosphate of magnesia and ammonia calculus was subjected to the action of a galvanic trough, its ingredients were separated, but again united, and fell to the bottom of the vessel in the state of powder; and by continuing the experiment for some time, the calculus became so soft that it was easily broken. Though these effects were produced, it naturally occurred, that its influence on the bladder would be too powerful to admit its application to a calculus in it; but in this they were agreeably disappointed, the wires from 150 pair of plates, when introduced through a canula into the bladder of a dog, previously distended with water, not occasioning the slightest apparent uneasiness; and on applying the wires to a calculus, it was found, after repeated trials, to be so acted on that it was easily broken.

Though galvanism has thus proved of infinite service, yet it is detrimental in many operations.

When, for instance, a metal is put into a solution of a salt, there may be no action; but if there be two metals, and in contact, an action may take place, by which one or both may be destroyed. This circumstance was noticed by Fabroni so early as the year 1799, and which he ascribed to a galvanic action produced by the metals. The influence of metals in decomposing salts, may be

illustrated by a very simple experiment. Thus, if a plate of silver be put into a solution of sulphate of copper, there is no change; but if, along with it, and in contact with it, there is also a plate of iron, the salt is instantly decomposed, and the copper is deposited on the silver. The inconvenience arising from galvanism is principally of this kind. The bolts that secured copper to the bottom of ships were formerly made of iron, which, being in contact, and in a solution of salt, excited galvanism, so that they were soon destroyed, the iron being the metal most easily acted on. When, then, pieces of metal are to be immersed in a saline solution, the same kind ought to be employed, that there may be no galvanic action, by which one or both may be affected. Accordingly, in the instance alluded to, copper bolts are now used.

Though galvanism has thus been a source of great inconvenience, yet the very principle on which it proves destructive, has pointed out a means of protecting valuable metal from being destroyed by fluids in which it is immersed.

When, for instance, a ship is copper-bottomed, there is a gradual action on the copper, so that a little of it is corroded, and its surface becomes covered with a greenish crust, and at the same time, small shell-fish and weeds adhere to it, which, by increasing the friction of the water on the vessel, impede its progress. It occurred to Sir H. Davy, that as the erosion depended on the union of the copper with oxigen, and then with acid, to prevent it, all that was necessary was to keep the metal from being oxidized, and this, he conceived, would be accomplished, by bringing it and the oxigen to the same electric state. Oxigen is an electro-negative, copper an electro-positive; but by bringing it in contact with zinc or iron, it becomes negative, and in this state will not, of course, unite with oxigen, which belongs to the same class; so that, though placed in a saline solution, it is not acted on by the acids, because, before it can combine with it, it must be oxidized. On a small scale, he found, that

copper, with a piece of zinc soldered on it, did not suffer any change, when kept in a jar of sea water; and by putting on pieces of the same metal on the copper sheathing of ships, after long voyages, they returned with the copper very little corroded. Though copper can thus be protected, there is a danger of earthy matter being deposited on it, from the decomposition of the earthy salts in the water, and affording a surface for the adhesion of shells and weeds. This, however, does not seem to be the case, when the protectors are of the proper size, and when the vessel is in motion. If lying in harbour, the copper is apt to be covered with them, but these are easily removed before going to sea. With respect to the proportion of the protecting metal, it depends, in a great measure, on the size of the vessel, and the velocity with which it moves. In the *navy*, about 1-250th of iron or zinc has been used. This is perhaps less than is absolutely necessary for the protection of the copper; but this is not of so much consequence as keeping the bottom clean, and which is secured by having the protector small. In other vessels, about 1-150th and even 1-100th has been used, and which is perhaps, in the generality of cases, about the requisite quantity.

The protector may be either soldered to the *outside* of the copper, or nails of iron or zinc may be driven into the sides of the vessel, and the copper then put on above these, taking care that it is in contact with them. In steam vessels, the protectors may be large, because, owing to the quickness with which they move, there is no chance of adhesion of weeds and shell fish, and the wear of copper is thus diminished at least two-thirds, (Ph. Tr. 1824, 1825.)

On the same principle, iron instruments are prevented from being rusted, by putting small pieces of zinc on them, which, by bringing them to an electro-negative state, prevents the iron from uniting with oxigen, and then with carbonic acid.

The influence of protectors is beautifully illustrated

by the immersion of sheets of copper in a solution of salt. For this purpose, having prepared a strong solution f sea salt, fill two jars with it, and place into one a plate of copper, and into the other, another similar, but on which there is soldered a piece of zinc, of about 1-100th of its size. In the course of a few days, a powder will be precipitated in both, which is white in the latter, but green in the former. The first is the earthy matter existing in the sea salt, along with oxid of zinc; the other is the same earthy substance, but with oxid of copper, or probably oxid in union with acid, derived from the salt decomposed. Now, in this instance, though there is in both decomposition, yet in the protected metal there is no erosion of the copper; for by the attachment of the zinc, the copper has acquired an electro-positive condition, and is therefore prevented from being attacked by the acids set free by the galvanic action.

For a full account of the modes of exciting galvanism, and its agency in affecting decomposition, in addition to the works already quoted, the reader is referred to Davy's Elem. of Chem. Phil.; Cuthbertson's Practical Electricity; Singer on Galvanism; Bostock on Galvanism.

Electro-Magnetism.

M. Oersted, professor of natural philosophy at Copenhagen, who had been previously engaged in an experimental inquiry into the nature of chemical, electrical, and magnetic forces, discovered in 1819, that the electricity of a galvanic battery had peculiar effects on magnetic needles, which induced him to prosecute the subject still farther, by which he has been enabled to establish an intimate connexion between electricity and magnetism, and has thus given rise to what is now called *electro-magnetism.*

Oersted found, that if a needle be suspended so as to be left to take its natural direction, and the connecting

wire of a battery * be placed *above* it, and in the same parallel line, the pole next the negative end moves to the *west*. If the wire be sunk, so as to come in the same horizontal plane with the magnet, the latter does not turn as before; it attempts to move vertically, but is, in a great measure, prevented by the manner in which it is suspended, and by the earths counteracting magnetic power, the inclination varying according to the relative position; the pole next which the negative electricity enters the wire, is *depressed* when the wire is on the *west*, and *elevated* when on the *east* side. If the wire be carried still farther down, so as to bring it *below* the needle, the pole next the negative end of the trough moves in a contrary direction; it is propelled to the *east*.

For recollecting these movements, Oersted has given the following formula: "The pole *above* which the *negative* electricity enters, is turned to the *west*; *under* which to the *east*."

If n be the needle, w the wire, and W, E west and east, they may also be represented thus,

$$\begin{matrix} w \\ n \end{matrix} = \mathrm{W} \quad \begin{matrix} n \\ w \end{matrix} = \mathrm{E}$$

These experiments prove that the electricity of the battery inclines the needle to move in a circle, which it would do but for its imperfect suspension, and for the earth, the magnetism of which tends to restore it to its original position, the moment it begins to turn. If, however, these interfering circumstances be removed, as when the needle is suspended, so as to allow free motion in all directions, and the earth's magnetism is counteracted by another needle, the movements become more distinct; and that there is this tendency to move as described, may be shewn by a particular adjustment of the apparatus. When, for instance, the connecting wire is brought near the centre of a properly suspended needle,

* By the *connecting* or *uniting wire*, is here meant one passing from the negative to the positive end of a trough

the latter, provided a battery of sufficient strength be used, instantly moves, and places itself at right angles to it, the poles being invariably in a certain position, according to that of the battery; and in this relative situation it continues, though the wire be moved round its centre, or it round the wire. Thus, if the positive end of a trough, placed before us, be on the right hand, and the negative on the left, a needle suspended *over* the uniting wire, will move till its *north pole is from us;* but if *under* the wire, the *north pole is towards us.* If the wire be drawn from the centre towards either end of the needle, the latter is instantly attracted, so that the former has the power of attracting both poles; and if, while in this position, the needle be turned, so as to bring near the wire the pole formerly at a distance, it is immediately repelled, and this occurs whether the north or south pole be approached; so that that part of the wire which originally attracted, now repels. If the wire, after having attracted the needle, be moved round the end, to the opposite side, the same point being always towards it, its attractive force increases till it comes to the extremity, but ceases when opposed to it; the moment, however, that it gets to the other side, it begins to repel, the repulsion becoming more and more powerful as it is moved along it, till it is brought to the end.

These experiments still farther prove the effect of the battery over a needle, and that any part of its connecting wire may be made attractive or repulsive of either pole, by mere change of position. It has been found, that the power of the trough, in producing these effects, does not depend on the nature of the metal of which the connecting wire is composed, a tube of mercury acting equally as well as any other metal; and the magnetic influence, it has been shewn, extends through different substances, as glass, in the same way as common magnetism. If, instead of a magnetic needle, one of brass, or a glass rod, or a stick of gum lac, be used, it is not in the slightest degree affected, (See Oersted's paper, An.

of Ph. xvi. and Historical Sketch of Electro-Magnetism, N. S. ii.)

M. Ampere has also shewn, that the battery itself has the same power over needles that the uniting wire has, provided the communication between the opposite poles be kept up; the moment, however, that it is broken, the effect ceases, which led to the supposition, that there are currents of electricity through the battery, but in opposite directions to that along the wire; and hence also the use of a needle, recommended by him as a *galvanometer*, or instrument for indicating the direction of the *electric current*, and the power of a trough for exhibiting electro-magnetic phenomena, (An. de Ch. et de Ph. xv.) the power being according to the declination, and the direction of the current ascertained by the position of the needle, which has its north pole always to the left of the current by which it is affected.

Another very important circumstance, noticed by Ampere, was the attraction and repulsion of wires connecting the opposite ends of a battery. When, for instance, two wires were suspended between the opposite poles, if the electric current passing along them is in the same direction, in other words, if they are similarly situated with regard to the trough, they attract each other; but if the current is in opposite directions, that is, if they be connected, the one with the one, and the other with the other pole, they repel each other. Between these and common electric attractions and repulsions, there is a remarkable difference; in fact, they are directly opposed to each other, for bodies *similarly electrified repel*, those *electrified at opposite poles attract* one another, while substances under the *influence* of *electric currents attract*, when the currents are in the *same*, and *repel* when they are in *opposite* directions. For exhibiting *electro-magnetic* phenomena, also, the circuit must be *complete*, whereas, for the production of *common* electrical effects, it must be *broken*.

The discovery of these important facts naturally led to the idea, that the battery, in other words, that elec-

tricity has the power of communicating magnetic properties; and that this is really the case, has been confirmed by the experiments of Davy and of Arrago, both of whom succeeded, nearly about the same time, in shewing the magnetic influence of the connecting wire itself, and the power it possessed of communicating magnetism to needles. They have shewn, (Arrago, An. de Ch. xv. Davy, Ph. Tr. 1821.) that when dipped into iron filings, it attracts them as long as the connexion is kept up, but when broken at either pole, it ceases to do so, the filings almost instantly dropping off; with brass or copper filings, there was no attraction.

Though in these cases the magnetism ceased when the communication with the trough was discontinued, they succeeded, though by different means, in giving permanent magnetic properties to needles. Davy found, that when iron bars were suspended near the connecting wire, some in the same parallel line, others at right angles to it, they all became magnetic; the moment, however, that the former were removed, the magnetic property ceased, but it was permanent in the latter, and the needles thus magnetised, had opposite poles, those placed *below* the wire, the positive end of the trough being east, having the *north pole* to the *south* of the wire, while those *above* had their poles in the reverse direction.

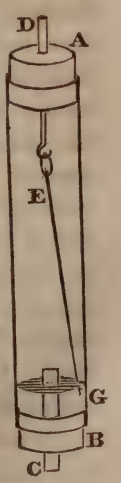
The method followed by Arrago in magnetising needles, suggested by Ampere, consisted in placing them in a *helix* of wire attached to, or rather forming part of, the connecting one, by which the magnetic property was more quickly communicated. And in this case, as in the experiments of Davy, the position of the poles varied according to circumstances. When the helix was so formed, that the convolutions were from *right to left*, above its axis, the end of the needle towards the negative one of the trough, pointed to the *north*, but with a helix, the turns being from *left to right*, the same end pointed to the *south*.

The magnetising power of the electricity of an electric

machine has also been proved by Davy, who succeeded in forming needles, by placing bars of steel across the wire through which the charge was transmitted, and the effect was produced though a space of several inches intervened, and even though vessels with water, or plates of metal or glass, were interposed.

Though, from what has been said, it may appear that the effects of the connecting wire of a battery over a magnet, are occasioned by an attraction or repulsion existing between them, Mr Faraday has proved, that they depend on a tendency which they have to revolve round each other. According to him, the centre of magnetic action, or true pole of a needle, is not at its extremity, but in its axis at a little distance from it; and this point has a tendency to move round the wire, and the wire round the point; and as the same effects, but in an opposite direction, are produced by the other pole, he supposes that each has the power of acting on the wire by itself, and accordingly the attractions and repulsions are merely parts of the revolving motion.

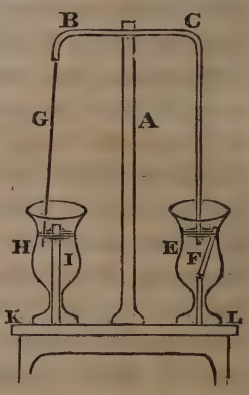
For exhibiting these rotatory movements, he has contrived different very ingenious sets of apparatus, the simplest of which is that in the annexed cut. It consists of a glass tube, into the open ends of which there are placed corks, A B; a magnet C, is passed through B, and into the tube a little mercury G, is poured, so as to leave the upper end of the magnet exposed. Through the cork A, there is passed a wire D, with a hook at its lower extremity, from which there is suspended a copper wire E, amalgamated at both ends, to give more perfect contact, and the lower one dipping into the fluid beneath. When this apparatus is made part of the chain of communication of a galvanic trough, by connecting the magnet with one end, and the wire D with the other, the copper wire E instantly begins to move round the magnetic pole, and continues to do so as long as the communication is kept up.



On reversing the pole of the magnet, the wire continues to move, but in the opposite direction. Suppose a watch dial on the surface of the cork A, and the *north* pole of the magnet in the tube, the wire, when its *negative* end is in the fluid, moves in the *same direction as the handles*, but if the *positive* extremity be in it, it goes in the *opposite direction*. When, on the contrary, the *south* pole is in the tube, the *negative* end of the wire, being next it, moves in the *reverse direction to the handles*, but the *positive* being next it, it goes in the *same* direction with them.

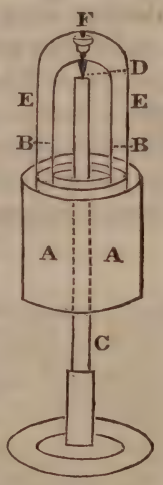
If, instead of keeping the magnet fixed, and the wire moveable, the latter be fixed, and the former moveable, on establishing the communication, the magnet begins to move, and continues to do so as long as it is kept up, the direction of the movement being the same as that of the wire.

These movements are beautifully illustrated by an apparatus, the contrivance also of Mr Faraday. It consists of a pillar A, supporting a wire bent at B and C, at right angles, the limb C being prolonged till it dips into a glass with mercury E, through the bottom of which there passes a metallic rod, having a magnet F fixed to it by a chain, so as to allow free motion, its upper extremity being above the surface of the mercury. The limb B of the cross wire has, immmediately after it is bent, another smaller one G, suspended from it by a chain, or ball and socket joint, so as also to move freely, its lower extremity dipping into mercury, in the cup H, through the bottom of which a magnet I passes, its end being above the surface of the fluid. The apparatus is fixed to a metallic rod KL, the metals which go through the cups, being made to rest on it, so as to keep up the contact between it and the magnets and wires. On connecting KL with the wires from



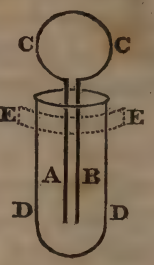
a battery, so that there shall be a current of electricity through the mercury and the cross bar on the pillar, the magnet F, and the wire G, begin to move, and in the directions already described.

The revolution of the wire round a magnet, is well illustrated by an apparatus contrived by Ampere, and which possesses the advantage of containing the trough by which the electric current is produced. With a slight modification suggested by Mr Barlow, the movements become more complete. It consists of a trough AA, formed of two cylinders of very thin copper, about 2 inches in depth, the outer one about 2, and the inner about $1\frac{1}{4}$ inches in diameter, joined below by a copper bottom. The inner cylinder has a copper wire BB, fixed to it, so that it can be suspended on a magnet C, which passes up within it, the suspension being by means of a fine pointed wire, from the bent part D. Into the trough is placed a cylinder of sheet zinc, which has also a wire passing from one side to the other E E, and suspended by a pointed wire passing down from the bent part F, and placed in a small cup containing a globule of mercury, fixed to the upper part of the bent wire E E, of the trough. When the trough is filled with diluted acid, and the apparatus suspended on a powerful magnet, the zinc plate revolves in one direction, and the copper trough in another, the direction varying according to the pole on which they are suspended. When on the north, the zinc revolves in the same direction as the handles of a watch, lying on the table with the dial up, while the trough moves round in the opposite one. If the apparatus be suspended on the south pole, the zinc turns in the reverse direction, while the trough goes in the same one with the handles.



A very simple apparatus, within the reach of every one, has been described by De la Rive, (Bib. Univers. March 1821,) for shewing the power of magnets over galvanic

troughs. It consists of a slip of copper and of zinc, A B, joined above by a curved copper wire CC, and placed into a small tube, DD, filled with diluted acid, so as to form a voltaic circuit. If the tube be passed through a cork, E E, and then put in a basin of water, on which of course it will float, on approaching a magnet, it is attracted and repelled according to the pole presented.



The above are a few of the leading facts of electro-magnetism. I conceive it foreign to the object of this work, to enter into a detail of the different opinions which have been given of the means by which the phenomena described are produced, more especially as none, even though some have been advanced by names of high authority, seem to account for them satisfactorily. The reader who wishes more minute information on the subject, is referred to the original papers of Oersted, Ampere, Arrago, and Davy, already alluded to, and to the historical sketch also already noticed, in the last of which he will find not only a full statement of facts, but also numerous references to the authors who have written on it.

PART VI.

ANALYTICAL CHEMISTRY.

It is not my intention to enter minutely into this department of the science; indeed, this would be altogether foreign to an elementary work. I intend to offer a few remarks on those subjects of general interest, such as mineral waters, detection of poisons, and the assay of some bodies much employed in the arts.

Mineral Waters.

Waters vary in purity, according to the source from which they are derived, and hence they have been divided into different classes, as rain, snow, or hail water, spring and river water, well water, and the water of lakes and ponds.

Rain water is by far the purest, particularly if collected at a distance from town, and some time after the shower has commenced. In winter, also, it is freer from foreign ingredients than in summer, as there are then fewer impurities floating in the atmosphere. The substances found in it, are common air, carbonic acid, and a minute quantity of super-carbonate, and muriate of lime; and Bergman states, that he has detected nitric acid, formed probably by the union of the ingredients of the atmosphere.

Well water is the rain which has penetrated the earth, and is collected in pits dug for the purpose. It is not so pure as the preceding, as it in general acquires some foreign matter from the soil through which it has passed. In addition to the substances already mentioned, it contains sulphate of lime, and more of the super-carbonate, which communicate *hardness*, or the property of not dissolving soap, (see p. 181.)

Spring and river water is also the rain, which has penetrated the earthy and strong strata of the globe, till, finding an issue in some less elevated spot, it escapes and produces running waters, varying in size according to their situation. During its passage through the earth, it undergoes the process of filtration, and escapes clear and transparent; but it is not pure, for it in general traverses beds of soluble matter, on which of course it acts. It accordingly contains atmospheric air, carbonic acid, carbonates and muriates of soda and of lime.

The water of lakes and ponds is also the rain, which, after penetrating the earth, has collected in depressions on its surface. It contains the same ingredients as the others, along with vegetable and animal matter, which has undergone putrefaction.

The water of marshes is still more loaded with putrescent animal and vegetable remains.

Spring waters are often impregnated with a great deal of foreign matter, that imparts peculiar qualities, in which case they are called mineral waters.

Mineral waters occur in various parts of the globe, differing in their ingredients according to the channel over which they have flowed; but besides this, they also vary in temperature, for though most of them are nearly the same as that of the surrounding medium, they are occasionally above it, and in some rare instances, actually reach that of ebullition.

Though the attention of man was early directed to these waters, particularly as a cure of diseases, it was not till about the end of the 17th century that a chemical investigation of them was undertaken, which seems

to have been first done by Boyle, who employed tests in detecting the substances they contain. In 1707, Geoffroy pointed out a mode of procuring their ingredients in the solid form by evaporation, and in 1726 Boulduc used alcohol as a means of separating them from the water which held them in solution. After the discovery of carbonic acid, by which some of their ingredients, not soluble in water, are kept dissolved, the modes of analysis were greatly improved, and two excellent treatises on them published, one in 1787 by Bergmann, the other in 1800 by Kirwan; and more lately Dr Murray, who had advanced a new view with respect to their constitution, has proposed a method of analysis, much more simple, and apparently more correct, than those of preceding chemists.

The examination of mineral waters is one of the most difficult pursuits of a chemist. It requires an intimate knowledge of the action of bodies on each other, and the utmost nicety in the manipulation, the quantity of matter on which he has to operate being so small. The analysis may be divided into two parts: 1*st*, the investigation of the physical qualities, with an account of the surrounding objects; and 2*d*, the chemical examination so as to ascertain the component parts.

Before proceeding to the performance of any experiments, it is necessary to ascertain the source from which the water is derived, the nature of the substances over which it has passed, and of the soil where it has its exit. We must attend also to any matter that may be deposited, and the taste, odour, colour, and temperature, should be noticed; the quantity discharged also in a given time, and the rapidity with which it runs, should be observed. This examination ought to be conducted at different seasons, both before and after rain, as it is likely that the quantity of fluid, and of course also its properties, may vary according to the state of the weather. The knowledge thus derived, may lead us in some respects to the nature of the water; thus, the smell will at once inform us whether sulphuretted hydrogen is present; its taste

will indicate whether or not it contains iron; and its sparkling, when poured from one vessel to another, will shew the presence of a gaseous fluid.

Having made these observations, we have next to proceed to the chemical analysis.

The substances found in mineral waters may be divided into gaseous fluids, the acids, the alkalies and earths, and the compound salts.

Atmospheric air is contained in all mineral waters, but the quantity is small; it seldom exceeds 1-28th of the volume of the fluid.

Oxigen gas likewise exists in them, but it is also in minute quantity. It is never found along with sulphuretted hydrogen, nor the compounds of iron.

Nitrogen has been detected in the Bath waters, and in those of Harrogate, and a few others.

Carburetted hydrogen has also been found, though rarely, and in very minute quantity.

Carbonic acid is a very common ingredient. Its quantity varies considerably, though, in general, it seldom surpasses that of the fluid. According to Higgins, however, 100 cubic inches of Pyrmont water contain 160.

Boracic acid has been found in some of the lakes of Tuscany, though it is, in general, in a state of combination.

Sulphuric and *sulphurous acids* have been observed in some of the waters of Italy, in the neighbourhood of Volcanoes.

Sulphuretted hydrogen is a very common ingredient.

Of the alkalies, *soda* is the only one that has been found free. It exists in considerable quantity in the waters of Geyser in Iceland, in which also there is silica held in solution, according to Dr Black, by the alkali. Nitric, carbonic, sulphuric, muriatic, hydro-sulphuric, and hydriodic acids, are frequently met with in union with *potassa*, *soda*, *lime*, *magnesia*, or *oxid of iron*; nitrates, however, very rarely occur. Perhaps the most common are carbonates, of which carbonate of lime, held in solution by excess of acid, is the most frequent, few waters existing without

it. Carbonates of magnesia and of iron also frequently occur, held dissolved by excess of acid. The most common of the sulphates are those of soda, lime, and magnesia; and of the muriates, that of soda is by far the most generally met with; indeed, it may be said to exist in all waters. Hydriodates have been found in some of the waters of Germany, and in that of Bonnington, near Edinburgh.

Besides the gaseous and saline substances above enumerated, *animal* and *vegetable matters* are occasionally observed, but these are probably to be considered accidental.

Owing to a difference in the proportion of the above ingredients, waters have been divided into classes, as the acidulous, sulphureous, chalybeate, and saline.

Acidulous waters are those that contain free acid, and are easily distinguished by their taste. Along with carbonic acid, they almost always contain muriate of soda and earthy carbonates, but it is the free acid that gives them their peculiar qualities. The waters of Seltzer, Spa, Pyrmont, Pouges, and Carlsbad, belong to this class.

Sulphureous waters are those having sulphuretted hydrogen, and are known by their smell. It is sometimes in a state of combination, but most frequently uncombined. The most noted of the waters of this class are those of Aix-la-Chapelle, Cheltenham, Harrogate, Moffat, and Lemington.

Chalybeate waters contain iron, and are also in general known by their taste. The iron is usually held in solution by carbonic acid, which is sometimes in such excess as to communicate acid properties, forming a subdivision called *acidulous chalybeate.* The waters of Tunbridge, Brighton, Harrogate, Cheltenham, Teplitz, Lemington Priors, are of this class.

Saline waters contain the saline ingredients already mentioned, as existing in mineral waters, in general, with the exception of free carbonic, sulphuretted hydrogen, and iron. Of course their properties depend on the nature and quantity of the matter in solution. As instan-

ces of saline waters may be mentioned those of Seidlitz, Lemington, Bath, Buxton, Bristol, Cheltenham, Epsom, Pitcaithly, Airthrie, Inverleithen. A table of the composition of mineral waters is given in the Appendix.

The water of the ocean differs from the preceding, in containing a large quantity of muriate of soda. It has a bitter disagreeable taste. Its specific gravity varies from 1026.9 to 1028.5. It freezes at 28.5, and during its congelation, deposits the whole of its saline ingredients; the ice, when melted, affording water almost as free from impurities as after distillation. The latest analysis is by Murray, who analysed it in three different ways, and obtained different results each time; but he places most confidence in the last. The following are given as the ingredients of 10,000 parts of the water from the Frith of Forth, (Ed. Ph. Tr. viii.)

Muriate of soda,	242.51	245.04	220.01
sulphate of magnesia,	7.86	17.04	
sulphate of soda,	9.99	2.66	33.16
muriate of magnesia,	34.49	28.63	42.08
muriate of lime,			7.84
sulphate of lime,	9.45	9.72	
	304.30	303.09	303.09

It was at one time supposed, that in different latitudes, and at different depths, the quantity of saline matter varied; but it is now known that the difference is very trifling, and does not follow any known rule with respect to change of situation. Considering the analysis of Murray as correct, at least with respect to the amount of saline matter, we may consider sea water as containing about 1-33d of its weight, or from 3 to 3.5 per cent.; but in addition to the ingredients mentioned by him, potassa, ammonia, and hydriodic acid, have been lately noticed as existing in it.

The water of the Baltic differs materially from that of the ocean; the former containing only about 1 per cent. of saline matter, though this varies according to the di-

rection of the wind. When from the west, it is about doubled.

The water of the Dead Sea also differs from that of the ocean. According to Marcet, it has not less than 24.5 per cent. of soluble matter, 100 parts consisting of

muriate of lime,	-	3.920
muriate of magnesia,	-	10.246
sulphate of lime,	-	.054
muriate of soda,	-	10.360
water,	-	75.420

The water of the River Jordan, Marcet found to be of the same composition. (Ph. Tr. 1807.)

Methods of detecting the Ingredients of Mineral Waters.

To ascertain the nature of the gaseous fluids, a retort must be filled with the water, and the mouth of it made to terminate under a jar of mercury standing on a mercurial trough. On the application of heat, the water gives off its elastic ingredients, the whole of which is expelled by continuing the ebullition for about ten minutes, and is collected in the jar. It may contain oxigen, nitrogen, carbonic acid, sulphuretted and carburetted hydrogen, and sulphurous acid; the two last, however, very rarely, more especially the sulphurous acid, which occurs only in volcanic countries. Though these different gases have been mentioned as existing in mineral waters, it must not be supposed that they are all to be met with in any instance, for some of them decompose each other; thus, if oxigen has been detected, we need not look for sulphuretted hydrogen.

Oxigen. The presence of this gas in the elastic fluid collected in the jar, is indicated by the introduction of a few bubbles of nitric oxid, by which red fumes of nitrous acid are produced, (vol. i. p. 216.)

Sulphuretted Hydrogen. By the immersion of a piece of paper soaked in sugar of lead, or by throwing up a little of the solution, the black sulphuret is instantly formed, provided this gas is present, (p. 32.) Instead

of sugar of lead, Dr Henry has proposed paper besmeared with the carbonate, which is blackened when the gas contains only about 1–20000th of sulphuretted hydrogen.

Carbonic Acid. When the gaseous mixture contains carbonic acid, on the introduction of lime water, there is an absorption, the fluid becoming turbid from the decomposition of carbonate of lime, (vol. i. p. 455.) The acid gas may also be indicated by potassa water.

Carburetted Hydrogen. Having removed the gaseous fluids already mentioned, by the use of the tests by which they are detected, to ascertain if carburetted hydrogen is present, a little oxigen must be introduced, and the mixture fired by electricity. If there is any diminution in volume, and if, on letting up lime water, it becomes turbid, it may be inferred that carburetted hydrogen is present, (vol. i. p. 232.)

Sulphurous Acid is detected by the introduction of peroxid of lead, by which it is gradually absorbed. Another method of detecting it, is by introducing fragments of borax, having previously removed the carbonic acid. The borax, when mixed after this with water, and exposed to heat, will give out the odour of sulphuretted hydrogen, provided the acid gas existed in the mixture subjected to analysis.

Nitrogen. Having removed the different gases above mentioned, should there still remain some, and if it extinguishes a taper, it may be considered nitrogen.

The saline ingredients of water are easily detected.

The Acids are indicated by the use of litmus, which, when they are free, is instantly reddened; but the effect is different, according as the acid is a fixed or volatile one. When the change is produced by sulphuric or muriatic acid, the colour is permanent on the application of heat; but it is fugitive if occasioned by carbonic acid or sulphuretted hydrogen, the original appearance returning. If, therefore, litmus paper has been used, it must be held before a fire; or if the infusion has been employed, the fluid must be boiled for some time.

Carbonic Acid in combination, is most easily detected

by the addition of solution of acetate of lead, by which a white carbonate is deposited; but as lead is thrown down by other substances, it is necessary to try the effect of nitric acid on the precipitate. All carbonates are decomposed by nitric acid; and as nitrates are soluble, it is generally said that a precipitate, if a carbonate, is soluble in nitric acid, (properly speaking, it disappears on its addition.) To try, then, if the precipitate by acetate of lead is carbonate, add a few drops of *pure* nitric acid*. If it is so, it will disappear. If it does not disappear, it is not a carbonate.

Sulphuretted Hydrogen is easily detected by acetate of lead, which throws down a dark-coloured precipitate, a sulphuret. Other metallic salts, as those of silver and mercury, are also similarly affected, but that of lead is the most delicate; besides, by its use both carbonic acid and sulphuretted hydrogen may be indicated at the same time. If, for instance, a drop of the solution be put into a fluid containing both, a white precipitate appears, but which almost instantly becomes black. In cases of this kind, when the quantity of matter in solution is very small, by far the best method of using the test is, to allow a drop of it to fall into the fluid from the end of a rod, as by this means streaks appear, and are easily observed by their being surrounded by a transparent fluid.

Nitric Acid. Though there is no direct test of this acid, a very ingenious method of detecting it has been proposed by Wollaston, founded on the solubility of gold in aqua regia, (p. 81.) Having concentrated the water by evaporation, a few drops of sulphuric acid are added, along with a grain or two of sea salt, unless a muriate exists in the water, in which case there is no necessity for it; a small piece of gold leaf is then put in, and the fluid boiled; if the water contain nitric acid,

* In using nitric acid in this and in the other trials to be mentioned, care must be taken that it be free from sulphuric and muriatic acids, which, owing to the mode of preparing it, it is likely to contain. For the method of purifying it, see vol. i. p. 390.

the metal disappears, owing to the formation of nitro-muriatic acid. (Quart. Journ. xvii.)

Sulphuric Acid. It has been already mentioned, that acetate of lead sometimes yields a white precipitate, not soluble in nitric acid. This is generally a sulphate, and hence the test is occasionally employed to detect sulphuric acid; but it is by no means a delicate one. The best is baryta, or any of its salts, which throw down a white powder. But baryta is precipitated by carbonic acid, and its salts by carbonates, so that to ascertain if the precipitate be sulphate or carbonate, add a few drops of pure nitric acid; if the former, it is insoluble.

Muriatic Acid. The most delicate test for this, is nitrate of silver; but before using it, it is necessary to add to the water a little nitric acid, to neutralize any free alkali, and decompose the carbonates. If, after this, the test gives a white precipitate, muriatic acid is present.

Hydriodic Acid. The only means yet known of detecting this acid in water, is to shew whether or not *iodine* exists in it; for it is in this state of combination the latter generally occurs. When iodine is in solution, the fluid gives a blue precipitate on the addition of solution of starch; but this is not to be expected when it is in the state of acid. The acid may, however, be decomposed by sulphuric acid, and its iodine set free; and hence the method of detecting it. For this purpose, to the water concentrated by evaporation, add *cold* solution of starch, and then throw in from the end of a glass rod a drop of sulphuric acid. If iodine is present, blue streaks will appear in the fluid, (vol. i. p. 274.)

The Alkalies are indicated either by litmus, or by turmeric, the former becoming blue, and the latter brown; and the fixed ones are distinguished from the volatile, by the permanency or fugitiveness of the colour on the application of heat. The alkalies, however, are not to be expected to be free; but though in union with carbonic acid, in which state they sometimes occur in a water, they affect the tests in the same way.

Supposing a fixed alkali to be detected, potassa is dis-

tinguished from soda by tartaric acid, which forms a sparingly soluble salt with the former; but with the latter, one easily dissolved. Before using the test, therefore, it is necessary to concentrate the water by evaporation; if, on adding the acid, a precipitate appears, potassa is present; if none is formed, the effect on the colour must have been produced by soda. When the potassa is in very small quantity, it requires the fluid to be well stirred with a *wooden* rod, in which case the only indication of its presence is a white streak where the rod is rubbed on the glass.

This test may also be used though the alkali is in a state of combination; it is liable, however, to be affected by salts of lime; so that if it is present, it must be removed. *(See Test of Lime.)*

Soda. There is no direct test for soda when in union. The only method of ascertaining its presence, is procuring the saline matter in crystals, by evaporation, and separating those of different forms. Should prismatic ones be obtained, in which we can indicate sulphuric, or cubical ones, in which we find muriatic acid, but cannot detect any base in either, we may consider the former to be sulphate, and the latter muriate of soda.

Ammonia. When ammonia is in combination, it is easily detected by evaporating some of the water to dryness, mixing the residue with its own bulk of slaked lime, and applying heat. If present, it will come off, and can be known by its odour; or if not in sufficient quantity for this, by holding a rod dipt in muriatic acid over it, by which the white vapour of muriate of ammonia will appear.

Lime. Oxalic acid is by far the most delicate test of this earth, but it is better to use it in a state of combination. When oxalate of ammonia is added to a water containing lime in any state of union, a white precipitate appears. It is necessary, however, if a free fixed acid be present, to neutralize it by ammonia, because oxalate of lime is soluble in acids. Ammonia is preferred to the other alkalies, or to any of the carbonates, because it does

not, though added in excess, decompose calcareous salts, so as to occasion any precipitation; and hence, also, the necessity of using an oxalate in preference to the acid itself, that its alkali may neutralize the acid set free from the lime, and prevent it from acting on the precipitate to be formed.

We easily know whether the earth is in union with a fixed acid, as sulphuric, or muriatic, or with a volatile one, as carbonic, because from super-carbonate of lime, the excess of acid is expelled by boiling its solution, and the neutral carbonate is deposited, whereas there is no change effected on the muriate or sulphate. If, therefore, we can detect lime both before and after boiling, it exists as a sulphate or muriate; if only before boiling, it is as a super-carbonate. In this last case, a thin film of carbonate appears on the surface of the water.

It has been mentioned, that tartaric acid, the test for potassa, acts on lime, and that when it is present it must be removed before using it. For this purpose oxalate of ammonia is added to the water, which must be afterwards filtered, and then evaporated.

Magnesia.—Though there is no direct test for magnesia, there are different methods by which its presence in a water may be indicated, but by far the best is the formation of the ammoniaco-magnesian phosphate. Before adding the re-agents, however, that are to throw it down in this state, it is necessary to remove the other earthy or metallic bases, by which they may be affected. The substance usually employed for this purpose is carbonate of ammonia, which precipitates the whole of them, but does not act on the magnesian salt. To ascertain if magnesia is present, add carbonate of ammonia in excess, (till litmus paper dipt in the water becomes blue) and filter if necessary, then put in solution of phosphate of soda; if there is a magnesian salt in solution, a white precipitate appears. Should, however, the quantity be small, it is necessary to stir the fluid well with a *wooden* rod, by which white streaks will be formed on those parts of the glass rubbed by it.

Silica is a very rare ingredient, and when it does exist, it is in very minute quantity. The best mode of detecting it is to evaporate the fluid to dryness, treat the residue with diluted muriatic acid, by which the salts and iron, if present, will be dissolved. If after this there is any residue which is not destructible by heat, it may be considered silica; but to prove that it is so, let it be fused with potassa, and it will form a compound soluble in water, and from the solution of which acids will throw down a white precipitate.

Iron.—The tests usually employed for detecting iron, are ferro-cyanate of potass, and infusion of galls, the former of which gives a blue, and the latter a black precipitate; but the mode of applying them requires to be varied according to its state of combination, and the other substances present. When the water contains sulphate, all that is necessary is to add the test, unless a free acid has been previously detected; in which case, when the tannin infusion is used, it is necessary to neutralize it, because the tannuret of iron is soluble in acids. As, however, the quantity of iron is in general small, should a slight excess of alkali be added, the whole of it may be precipitated, and thus prevent the action of the test, it is better first to put in the galls, and then the alkali, suppose carbonate of ammonia, by which, if iron is present, the dark colour will instantly appear. In this case the precipitate is not exactly of the same colour as when the tannin unites directly with the iron; it has a purple tinge, the alkali somehow or other acting on it. With respect to the ferro-cyanate, as it requires the iron to be in its maximum state of oxidation, should the blue tinge not appear when it is added, it is necessary to leave the fluid exposed to the air for a few hours, to allow the metal, if not in this state, to absorb oxigen *.

Iron very frequently exists in waters as a super-carbo-

* In using this test, we must take care that it does not contain excess of iron, which it is apt to do. This is known by the addition of a drop or two of acid to its solution; if pure, it does not alter its appearance; if impure, it becomes blue.

nate, in which case the tests do not act on it, but may be made to do so by the addition of a drop or two of sulphuric acid, which brings it to the state of sulphate.

Methods of ascertaining the quantity of the different ingredients.

The total amount of gaseous fluids is ascertained by taking a flask with a long bent neck, the capacity of which is known, filling it with the water, and applying heat so as to cause it to boil for some time. Having collected the elastic fluid over mercury, and made the necessary corrections for temperature and pressure, (vol. i. p. 167.) so as to find its actual quantity, the tests are to be applied to ascertain the proportions of each.

By throwing up solution of acetate of lead, the volume of *sulphuretted hydrogen* is ascertained.

By the introduction of water of potass, the *carbonic acid* is indicated.

The amount of *oxigen* is discovered by mixing the gas with twice its volume of hydrogen, and firing it by electricity, (vol. i. p. 202.) one third of the diminution being allowed for oxigen. Instead of this, the spongy platinum is now preferred, the process being more easily managed than the other, (vol. i. p. 203.)

Should carburetted hydrogen be present, its volume is discovered by mixing the gas with twice its volume of oxigen, firing it in the same way, and after washing the residual gas with lime water, allowing one third of the loss for carburetted hydrogen, (vol. i. p. 232.)

The amount of absorption by peroxid of lead will give the volume of *sulphurous* acid. When, however, this gas exists in the elastic fluid, the peroxid must be used before any of the liquid tests are employed, because sulphurous acid is easily absorbed by water.

The residual gas, after removing the preceding, indicates the quantity of *nitrogen*.

Instead of boiling the water so as to collect the gaseous matter, the quantity of carbonic acid and of sulphuretted

hydrogen may be discovered, by passing them through fluids containing substances by which they will be precipitated. For this purpose, having put a certain quantity of the water into a retort with its neck bent at right angles, when the proportion of carbonic acid is to be found, the mouth of it is placed in a bottle with lime or barytic water, excluding as much as possible the atmospheric air, and heat applied so as to cause it to boil. By continuing the ebullition for some minutes, the whole of the gas is expelled, and by collecting and weighing the carbonate formed, the weight, and consequently the volume of carbonic acid gas, is ascertained. In the same way, by putting the mouth of the retort into acetate of lead, and boiling, sulphuret of lead is deposited; so that by weighing it, the volume of sulphuretted hydrogen is found. In the former instance, 100 grains of carbonate of baryta are equal to 47.5 cubic inches of carbonic acid; and in the latter 100 grains of sulphuret are equal to 38.5 cubic inches of sulphuretted hydrogen *.

To ascertain the quantity of saline matter in solution, by far the most accurate method is to evaporate cautiously a certain quantity of the water in a glass or Wedgewood basin nearly to dryness, then wash out with distilled water the residue into a smaller glass vessel, and again evaporate, after which the saline matter must be kept at a temperature a little above 212, so as to expel the whole of the moisture. When dry, it must be scraped off carefully and weighed, or by weighing the vessel before and after the evaporation, the additional weight will give that of the saline ingredients.

With the view of finding the proportions of the diffe-

* 100 grains of carbonate of baryta contain 22 of acid; 100 cubic inches of carbonic acid weigh 46.5 grains; so that

as 46.5 : 100 : : 22 : 47.5

100 of sulphuret of lead contain 13.3 of sulphur. Sulphuretted hydrogen is composed of 20 of sulphur, and 1.25 hydrogen; now as

20 : 1.25 : : 13.3 : 831

100 cubic inches of sulphuretted hydrogen weigh 35.9,

and as 35.9 : 100 : : 13.831 : 38.5

rent acids and bases, a certain quantity of the water being taken, nitrate of baryta is first to be added, by which carbonate, or sulphate of baryta, or probably both, will be thrown down. By weighing the precipitate, and afterwards washing it with muriatic acid, and again weighing it, the quantity of *carbonate* and *sulphate* may be discovered, by deducting from the weight of the original precipitate, the loss occasioned by the washing with acid. The loss is carbonate, the residue sulphate of baryta; 100 grs. of the former, are equivalent to 22 of *carbonic acid*, (vol. i. p. 474.) 100 of the latter to 33.89 of *sulphuric acid* *, (vol. i. p. 475.)

To the filtered fluid, nitrate of silver being added, the muriatic acid is deposited. 100 grains of the precipitate, when dried, indicate 19.1 of *muriatic* acid, (p. 90.)

To another similar portion of water, add oxalate of ammonia, and oxalate of lime falls; the precipitate, when dried cautiously, will indicate the quantity of *lime*, 100 grains being equal to 43.75, (p. 240.)

* In forming and weighing the precipitates, certain precautions are necessary. In the first place, care must be taken that the whole of the substance tested for is thrown down. This is done by adding the precipitant, as long as it seems to occasion precipitation; allow the fluid, after stirring it, to remain at rest for some time; and when the powder has subsided from the surface, take out a drop on the end of a glass rod, and having placed this on a plate of glass, touch it with a drop of the test; if a precipitate is formed, more of the test must be added to the fluid, and in this way the process must be repeated, till the drop removed does not become turbid on the addition of the test. This precaution applies to the precipitation of all the ingredients. Different methods are followed in collecting the precipitates, so as to weigh them. By far the most accurate, is to allow the powder to fall to the bottom of the glass; pour off the supernatant fluid, throw in distilled water, again allow to subside, and pour off; and in this way repeat the process till the water comes off pure, which is ascertained by testing it for any of the substances which was known to exist in it at the commencement of the experiment. After this, pour the residue containing the precipitate, into a glass basin, washing out the vessel with distilled water, and then evaporate to dryness; but to save time in evaporating, the greater part of the liquid may be poured off, by allowing the powder to fall to the bottom. The residue, when dry, is to be scraped off and weighed, the adhering particles being removed by means of a camel's hair brush. Another mode of collecting the precipitate is by filtration, and for this, smooth unsized paper should be used, because from it

To the filtered fluid add carbonate of ammonia in excess, filter if necessary, then add phosphate of soda, and stir the fluid well. The precipitate, which is phosphate of magnesia and ammonia, becomes phosphate of magnesia when exposed to a red heat; 100 grains are then equivalent to 40.16 of *magnesia*, (vol. i. p. 488.)

Different methods have been followed for finding the quantity of iron. When the ferro-cyanate of potass is employed for this purpose, its solution must be added to another similar portion of water, and the precipitate, after being washed, must be dried very cautiously; and as it is difficult, nay almost impossible, to remove it from the filter, the filter ought to be weighed before being used, and again weighed with the precipitate when dry; 100 grains of the blue ferro-cyanate, according to Porret, are equal to 34.23 of *peroxid of iron*, (p. 17.)

Berzelius has proposed to throw down the iron by benzoate of soda; in which case, all that is necessary is to add it to the water, collect the precipitate, and dry it by a gentle heat,—100 grains indicate 25 of peroxid, (p. 246.)

There is still another method of finding the quantity of iron. It depends on the insolubility of the peroxid in nitric acid. For this purpose ammonia is added in excess to the water, and the precipitate, after being washed and dried, is exposed to a red heat for some time, to per-oxidize the metal. It is then to be washed repeatedly with water, and afterwards with nitric acid, by which the different ingredients are dissolved, but the oxid is left. Its weight indicates that of the iron in solution.

the powder is most easily removed. Having thrown the fluid on the filter, the precipitate left on it must, after the filtration ceases, be washed with distilled water, till it comes through pure, which is known by the process already stated. The filter is then to be removed cautiously from the funnel, placed on a metal plate, and dried over a lamp or chauffer, after which the precipitate may be scraped off and weighed. Or the filter, after being dried, may be weighed before pouring the fluid into it, and again weighed with the precipitate; but in this case the weighing must be finished as quickly as possible, after removing the paper from the heat, because it absorbs moisture rapidly from the air.

Different methods have been recommended for finding the *state of combination* of the ingredients, and the proportion of the compounds formed by their union, as by evaporation and separation of the salts by alcohol and by water. There is every reason, however, to believe that these are not accurate; indeed, the experiments of Dr Murray warrant the conclusion, that the salts obtained by evaporation are not the same as exist in solution, new affinities having been brought into play during the performance of the analysis, by which decompositions are effected, and new salts are formed. According to him, (Ed. Ph. Tr. viii.) two views may be entertained with respect to the state of combination of saline bodies dissolved in water. When there are two acids and two bases, they may be united by the pure force of affinity; so that those between which it is most powerful, will be combined. Thus, when sulphuric acid, muriatic acid, soda, and lime, have been detected in it, if they are united merely by attraction, the salts will be sulphate of lime, and muriate of soda. But it is well known that affinity is modified by external circumstances; so that when any of these operate, combinations may be formed different from those mentioned. Thus, if the quantity of water be small, the compounds stated are produced; but if great, there is every reason to believe that it may have some effect, and others will be the result. In the former case, cohesion has its influence; so that those between the particles of which it is strongest, are usually found to exist; but in the latter, it is supposed to be the reverse, substances being formed between the particles of which there is little cohesion; so that in this case, the most soluble salts are produced. When, then, the acids and bases mentioned are in solution with a large quantity of water, instead of sulphate of lime and muriate of soda, they are as muriate of lime, and sulphate of soda.

This opinion of Murray is supported by several facts. Thus it often happens, that by the evaporation of water, a substance is obtained in greater quantity than it could hold in solution; so that it must have been formed dur-

ing the process. Again, substances are frequently found in a water, which decompose each other when their solutions are concentrated. Thus, carbonate of soda occasionally occurs along with an earthy salt, though it is well-known it precipitates both lime and magnesia.

Many mineral waters also afford different salts, according to the mode of analysis. Thus, sea water, by slow evaporation, yields muriate of soda, muriate of magnesia, and sulphate of magnesia; but when it is boiled to dryness, and the residue treated with alcohol, the products are muriate of soda, muriate of magnesia, and sulphate of soda.

The views of Murray just stated, afford, probably, the most accurate method of analysing waters, so as to ascertain what salts they contain. All that is necessary, is, after finding, by the use of the tests, the different substances in them, to *combine them so as to form the most soluble salts.* He has proposed the following formula as applicable to almost all waters.

All waters may be brought under the class saline, for, by the application of heat, the free carbonic acid and sulphuretted hydrogen are expelled from the acidulous and sulphureous, and the iron may be precipitated from chalybeate by ferro-cyanate of potass, so that the substances left after this are carbonic, sulphuric, and muriatic acids, with soda, lime, and magnesia. Supposing the whole of these present, the water must be evaporated, stopping before there is any deposition, and muriate of baryta added, *avoiding an excess.* The proportions of carbonic and sulphuric acid are found as already noticed, (p. 430). By this the whole of the salts are brought to the state of muriates; oxalate of ammonia is next to be thrown in, to precipitate the lime; and to the filtered fluid, carbonate of ammonia, and phosphate of ammonia, are to be added, to throw down the magnesia. The residual fluid now contains only muriate of soda. It must be evaporated to dryness, and the product exposed to a red heat, by which the salt is obtained.

The muriatic acid in the salt thus procured may, how-

ever, be different in quantity from what originally existed in the fluid; part of the soda may have been disengaged from the other acids, and have united with that of the barytic salt, in which case the acid is greater than it ought to be; or the soda may be in less quantity than could neutralise the whole of the acid, part of the latter having been united with the other bases; if so, the acid set free during the addition of the ammoniacal salts, would combine with the ammonia, and form muriate, which would be contained in the residue of the evaporation, along with muriate of soda, but would be volatilised by the heat, so that the muriatic acid in this instance would not indicate the whole that existed in the water. Though the muriate of soda, therefore, obtained by this process, gives the whole of the soda, it does not yield the quantity of muriatic acid. This may, however, be ascertained by adding to another portion of water, nitrate of silver, to throw the acid down. Having thus ascertained the proportion of the different ingredients, they are to be combined, so as to form the most soluble salts. Thus, in his experiments on sea water, Murray found, that a pint contained

lime,	2.9
magnesia,	14.8
soda,	96.3
sulphuric acid,	14.4
muriatic acid,	97.7
	226.1

which he inferred existed in it, as muriate of soda, muriate of lime, muriate of magnesia, and sulphate of soda. The quantity of sulphate of soda, equivalent to 14.4 of sulphuric acid, is 25.6, the remainder of the soda 85.1, is united with 74.2 of muriatic acid, and forms 159.3 muriate of soda. The muriate of lime equivalent to 2.9 of lime, is 5.7; the 14.8 of magnesia are combined with the remainder of the muriatic acid, to form 35.5 muriate of magnesia, so that the saline contents of a pint of the water, according to this mode of determining them, are,

muriate of soda,	159.3
——— of magnesia,	35.5
——— of lime,	5.7
sulphate of soda,	25.6
	226.1

If this view of the composition of mineral waters be correct, the component parts of those analysed by other means, will be different from what has been stated. Thus, those which have yielded sulphate of lime, and muriate of soda, it is inferred, contain muriate of lime, and sulphate of soda; but though this is the case, the proportion of acids and bases being given, it is easy to find the composition, according to this mode, without repeating the analysis. We have only to find the equivalents of the different salts, which is done by the sliding scale of Wollaston, (see Appendix;) thus, 100 sulphate of lime are equal to 81.5 of muriate of lime, and 100 muriate of soda are equivalent to 122 of sulphate of soda.

The mode of analysing waters now stated, is attended with much less labour, and it is probable, leads to results more accurate than those obtained by any other means. A strong argument in its favour, is its enabling us to detect in them substances, which act powerfully on the animal system, and thus to account for the medicinal effects of some, which cannot be done by the other modes. Bath water, for instance, according to the analysis by evaporation, contains, in a pint, about 9 grains of sulphate of lime, 3.3 of muriate of soda, 3 of sulphate of soda, 0.8 of carbonate of lime, with a minute quantity of silica and iron, all of which are either so inert, or in such small quantity, as to be incapable of producing any effect on the system; but, according to Murray's view of it, it contains no less than 3.1 grains of muriate of lime, a very active ingredient, and to which, if his views are correct, its medicinal properties are probably to be ascribed.

Though allowing the correctness of Murray's views with respect to the state of combination of the acids and bases, I am not inclined to adopt the formula recommended, with the view of finding their proportions, it is so

extremely difficult to avoid adding an excess of the tests, which, if done, must materially affect the result. Thus, if too much muriate of baryta be employed to precipitate the sulphuric acid, it adds to the weight of muriatic acid, and any excess of phosphate of ammonia will be left with the muriate of soda. I conceive the analysis to be more easily conducted, and with as much, if not with more accuracy, by using different portions of water for the acids, earths, and iron. To one portion, for instance, say a pint, add nitrate of baryta, to throw down the carbonic and sulphuric acid, their proportion being found as stated at p. 430, and to the filtered fluid, add nitrate of silver to throw down the muriatic acid,—to another pint, add oxalate of ammonia, to deposit the lime, and to the filtered liquor add carbonate of ammonia in excess, again filter if necessary, and add phosphate of soda to precipitate the ammoniaco-magnesian phosphate. The quantity of iron is most easily ascertained by adding the proper test to a third portion of fluid.

Having thus found the proportion of the different ingredients, should the amount of them be less than the quantity of saline matter procured by the evaporation of a pint, we may infer the deficiency to be soda; and this conclusion we may consider as correct, if, after having united the bases with their equivalent of acids, so as to form the most soluble salts, there is an excess of acid, and this excess requires, for neutralization, a quantity of soda equal to the deficiency.

Thus, suppose the water yields, by evaporation, 47.84 of saline matter, and the tests indicate, of

sulphuric acid,	18.6
muriatic acid,	9.64
lime,	7.2
magnesia,	9.3
	44.74
the deficiency is	3.1
	47.84

Now, 7.2 of lime require 6.95 of muriatic acid, and

9.3 of magnesia, 18.6 of sulphuric acid for saturation, thus leaving an excess of 2.69 of muriatic acid. But 2.69 of this acid require 3.1 of soda to form muriate of soda, so that, in this instance, we would be right in inferring the deficiency to be soda.

For fuller information on the modes of conducting the analysis of mineral waters, the reader is referred to the Essays of Bergman, Kirwan, and Scudamore, on Mineral Waters, Murray's paper, Ed. Ph. Tr. viii. Thenard's Analytic Chemistry, translated by Children. See also Faraday's Chemical Manipulation, where much valuable information is given with respect to the mode of conducting chemical experiments.

Detection of Poisons.

The substances generally administered as poisons, in this country at least, belong to the mineral kingdom; indeed, almost the only ones employed are, arsenous acid, corrosive sublimate, and sugar of lead. Of late, however, oxalic acid, hydro-cyanic, and some of the preparations of opium, have been used, the last particularly, on the continent. It is my intention, in this section, to describe the methods of detecting these, when they are supposed to exist in the contents of the stomach or alimentary canal.

Detection of Arsenic.

When arsenic is administered as a poison, it is usually in the state of arsenous acid, in which form it is soluble in water, so that in cases of this kind it is to be looked for in the contents of the stomach, and upper part of the alimentary canal, or in any matter that may have been ejected by vomiting. When given, however, in considerable quantity, it may be observed in white powder among the rugæ of the coats of the stomach, in which last case it is easily detected; but wher it is in the fluid contents, its detection becomes a matter of considerable difficulty, not so much from the want of tests, as from these being so liable to be affected by the sub-

stances likely to be present; and it is from not keeping this in view, that we have such discordant statements with respect to it. Indeed, it is to be regretted, that many who have had the merit of recommending delicate tests of arsenic, have entirely overlooked this; for had they operated on fluids of as compound a nature as the contents of the stomach, instead of transparent colourless ones, they certainly never would have asserted, as some have done, that there is no necessity for having recourse to other tests, those recommended being so delicate as at once to detect arsenic, though dissolved in several thousand parts of water.

These remarks are applicable to the liquid tests, as they are called, which, though sufficiently delicate, are extremely fallacious; and hence the necessity of having recourse to experiments in the dry way, or the reduction of the matter, so as to make it yield arsenic in its metallic state; indeed, in every case of suspected poison, unless we succeed in this, however delicate the liquid tests may be considered, we are, even though we procure precipitates, by no means warranted in concluding that arsenic is present. We ought to recollect, that the life of a fellow being is at stake, and that on our conclusion depends, in a great measure, the verdict of the jury. Hence also the necessity of proceeding to the analysis with a mind altogether unbiassed. As chemists, we ought to have nothing whatever to do with the symptoms previous to death, nor the appearances on dissection, and far less with any evidence that is to be brought against the prisoner; indeed, it would be well, if, in every case of the kind, the suspected fluid were given to others, than to those who have been engaged, either in the treatment of the patient, or in the inspection of the body, as it has too often happened, that from what has been observed before and after the death of the person suspected to be poisoned, individuals have undertaken the analysis of the contents of the stomach, in the hopes that they would detect arsenic, and must have of course grasped eagerly at every circumstance that gave even the faintest evi-

dence of its presence; and hence it has happened, that from a combination of these, they have come to the conclusion, that they have detected it, when in reality they had no grounds for doing so.

Though little or no reliance is now placed in the liquid tests, I think it proper to notice them, chiefly with the view of pointing out their fallacies, and also because some of them are employed to afford precipitates, from which we endeavour to procure the poison in its metallic state. They are sulphate of copper, nitrate of silver, and sulphuretted hydrogen.

Sulphate of copper. When solution of sulphate of copper is added to that of arsenous acid, there is no decomposition, but when an arsenite is employed, a green powder, well known by the name of *Scheele's green*, an arsenite of copper, is deposited. It has therefore been recommended to boil the fluid suspected to contain arsenic, with sub-carbonate of potass, and after filtration, to add the test,—if arsenic is present, the green precipitate will appear.

The introduction of the alkaline carbonate, however, gives rise to fallacy, because sulphate of copper is decomposed by it, and a carbonate is deposited, which, though it is easily distinguished from the arsenite when thrown down from a colourless liquid, the one being blue, the other green, yet, as in experiments of this nature, it is more than likely that we are operating on a coloured fluid, we are not to expect it to be of its proper colour. We find, accordingly, that the carbonate of copper, when formed in a fluid of this kind, frequently cannot be distinguished from the arsenite, owing to its having taken the colouring matter along with it. It is stated by some, however, that by repeated washing, the precipitate, if a carbonate, will become blue, the coloured medium through which it is viewed being removed; but this is not always the case, the colouring matter being frequently so intimately incorporated with it, that it cannot be separated.

To get quit of the fallacy arising from the use of carbonate of potass, it has been recommended to employ

ammonia, which, though it occasions a precipitate from the test, almost instantly re-dissolves it. The form in which it is generally employed, is the ammoniuret of copper, which, when added to arsenous acid, causes the formation of the green precipitate. Even in this form, however, it is not free from fallacy; for, allowing that there is no arsenic, should phosphoric acid, or any of its salts, be present, phosphate of copper is deposited, which, though blue, may, from its taking the colouring matter along with it, assume the appearance of the arsenite.

From the above remarks, it is evident that the copper test cannot be relied on when employed in the manner stated. There is one method, however, of using it, provided we wish to trust to liquid experiments, apparently free from fallacy. It is, to add the sulphate to the fluid, not boiled with any alkaline matter, filter if necessary, and to the filtered fluid add a drop of ammonia, by which, should a green precipitate be formed, it is likely to be an arsenical one; for, on the addition of the test, any phosphate present must have been precipitated.

Nitrate of silver. When nitrate of silver is added to arsenous acid, there is no decomposition, but when an arsenite is employed, a yellow precipitate, an arsenite of silver, is deposited. It has been proposed, therefore, to use the nitrate as a test of arsenic; but as it is liable to be affected by other substances, different methods of employing it have been recommended. If the fluid supposed to contain arsenic, has been boiled with carbonate of potass, the alkaline carbonate itself, even though no poison is present, will throw down a precipitate, which, though of a colour altogether different from that of the arsenite, yet may, from its taking colouring matter along with it, assume somewhat of the same appearance. To get quit of this source of error, it has been proposed to employ ammonia, which, though it at first acts on the nitrate, throwing down a precipitate, yet instantly re-dissolves it; and as arsenical precipitates are also soluble in this alkali, with the view of avoiding an excess, it has been proposed by Mr Hume (Med. Ch. Tr. ii.) to em-

ploy the ammoniuret, prepared by adding water of ammonia to the solution of the nitrate of silver, till nearly the whole of the precipitate at first formed, is re-dissolved. When this is added to a fluid containing arsenous acid, of course not boiled with any alkaline matter, the yellow arsenite is formed.

Though, by using the test in this way, one source of fallacy is got quit of, yet other substances than arsenic may, and frequently do exist in the fluid, which will throw down precipitates that may be mistaken for it. It is well known that nitrate is decomposed by sea salt, and though the precipitate, when pure, is white, yet by its combining with colouring matter its appearance may be altered. Phosphate of soda is also another which decomposes the nitrate, and throws down a precipitate so nearly the same as that of the arsenite, that it is difficult to distinguish them *.

Though the test is liable to fallacy when used in the manner stated, yet there is one way of applying it apparently free from it. It has been already mentioned that nitrate of silver is not affected by arsenous acid, but that sea salt and a phosphate decompose it; hence a method of getting quit of the sources of fallacy, indeed it is the only way of using the test that can be relied on. For this purpose, nitrate of silver is added to the fluid, not boiled with any alkaline matter, by which the muriates and phosphates, if present, are deposited, taking

* It has been mentioned by writers of high authority, that we never can mistake the phosphate for the arsenite, the one being a flocculent precipitate, the other a fine powder; and as the one is of a dark, the other of a pale yellow colour; statements made by such as must have performed their experiments on *transparent colourless fluids*, which we are not to expect when examining one suspected to contain poison; but even allowing that we do, surely no one would, from such a slight difference in the appearance or colour of a precipitate, swear to the presence of arsenic, when the life of a fellow being is at stake. It has been mentioned, also, that the phosphate is distinguished from the arsenite, by its *instantly becoming of a dark brown colour* when exposed to sunshine, while the arsenite *changes its colour slowly*, [Paris's Pharmacologia.] Now, though this enables us to say that phosphate is present when the precipitate is blackened, yet it does not indicate whether or not there is any arsenite.

along with them the whole or greater part of the colouring matter, so that the fluid, when filtered, passes through nearly colourless; and on the addition of ammonia, will, if it contain arsenic, give a yellow precipitate. As, however, the arsenical precipitate is soluble in this alkali, we must be cautious in the addition of it, for any excess will prevent its deposition. The safest way of using it, is to put it on the end of a rod; or the rod dipt in ammonia, may be held over the surface of the fluid, which will instantly be covered with a yellow crust.

Sulphuretted Hydrogen. When sulphuretted hydrogen is passed through a fluid containing arsenous acid, a yellow precipitate, a sulphuret, is formed. It must not, however, be supposed from this, that sulphuretted hydrogen may, in this way at least, be employed as a test; there are several other metallic salts that yield a precipitate nearly of the same colour, as those of antimony and cadmium; but though fallacious when thus employed, the sources of error may be removed. When the gas is passed through solution of an arsenite instead of arsenous acid, there is no precipitation of the arsenic, the alkali preventing the formation of sulphuret; but on the addition of any acid to neutralize the alkali, the sulphuret is formed and deposited. Hence a method, and it is probably the best, of using sulphuretted hydrogen as a test, not only because, by the introduction of the alkali, most metallic salts will be decomposed, but the arsenous acid is itself rendered more soluble by its uniting with it; besides, should sulphuret of arsenic have been administered as the poison, though insoluble, it is acted on by the alkali, and afterwards becomes soluble. In using the test in this way, the fluid ought to be boiled for some time with potassa, and sulphuretted hydrogen passed through it when cold, after which it must be filtered, and to the filtered liquor a few drops of any acid added; if arsenic is present, the sulphuret will be deposited generally of its proper yellow colour; for by the transmission of the gas through the fluid, there is usual-

ly precipitation, by which part or the whole of the colouring matter is removed *.

Chromate of Potass.—When this salt is added to solution of an arsenite, the fluid acquires a green colour from the arsenous, depriving the chromic acid of part of its oxigen, and converting it to oxid, which is held in solution; and hence it has been recommended by Dr Cooper as a delicate test of arsenic, (Silliman's American Journ. iii.) This is not, however, to be considered a test of arsenic, for there are other substances that will produce a similar effect; besides, it is of no value whatever unless we are operating on a transparent colourless fluid.

Tests by reduction. From what has now been said, it is evident that the detection of arsenic by liquid tests, in fluids containing a variety of ingredients, particularly vegetable and animal matter, as is likely to be the case with the contents of the stomach, is by no means so easy as has generally been described, the tests being so liable to be affected by the substances present. (See a paper on this subject by Dr Christison, Ed. Med. and Surg. Journ.) This has led to the necessity of having recourse to experiments in the dry way, or the reduction of the matter so as to make it yield arsenic in its metallic

* Instead of passing the gas through the fluid, boiled with potassa, some have recommended that a hydro-sulphuret should be used; but this mode of applying the test is very fallacious, for should the hydro-sulphuret not be recently prepared, it may have become sulphuretted hydro-sulphuret, in which state it will yield a yellowish precipitate when the acid is added; which is merely the excess of sulphur of the salt. Some have even recommended a sulphuretted hydro-sulphuret as a test, remarking that, on adding it to a fluid containing arsenous acid, a yellow sulphuret is deposited. Now, though in this instance a yellow powder is precipitated, it does not contain arsenic. The arsenous acid acts in the same way as any other acid, it unites with the alkali, liberates sulphuretted hydrogen, and deposits the excess of sulphur, so that the whole of the arsenic remains in solution. This shews how completely inert the sulphuretted hydro-sulphuret of potass must be when given as an antidote, unless an acid is administered at the same time to remove the alkali which the arsenic has taken from it, and allow the sulphuretted hydrogen to form sulphuret.

state, which is to be known either by its smell when in vapour, or by its appearance*.

When arsenous acid is thrown on burning coals, or when it is mixed with charcoal and put on a red hot plate of iron, it is reduced and converted into vapour, in which state it emits the odour of garlic. It has been proposed, therefore, to evaporate part of the suspected fluid to dryness, and treat it in the way stated, by which, should arsenic be present, the alliaceous odour will be emitted; but this is not to be depended on, for substances frequently exist in the contents of the stomach, which will, when heated, give a similar smell; and again, though the fluid contains arsenic, we may fail in perceiving it, owing to the decomposition of the animal and vegetable matter, and the evolution of gases, having a strong odour.

Another method recommended, and still practised by some, is to place a little of the residue of the evaporation, along with black flux, between two copper plates, tied together by wire, and subject it to a red heat; if arsenous acid is present, the carbon of the flux will deprive it of its oxigen, and reduce it to the metallic state, and the copper, from its combining with it, will acquire a dense white coating. This test is, however, more fallacious than any of the others, for other metallic salts, particularly those of antimony, communicate to copper a coating, which it is impossible to distinguish from that of arsenic.

There is still another mode, and which, if we succeed in it, is decisive of the presence of arsenic; but there are difficulties attending the performance of the experiment, that render it by no means to be depended on.

When arsenous acid is mixed with black flux and heated, the arsenic is brought to its metallic state, and as it

* It has been proposed by Phillips, to decolorize the fluid by filtering it through animal charcoal, by which, certainly, we are enabled by the use of the tests to obtain the precipitates of their proper colour; but even though we do, it is necessary to attempt the process of reduction with them, so that the procuring them in this state is of little consequence.

is easily volatilized, it rises in vapour; so that by conducting the experiment in close vessels, it may be condensed and collected. The best apparatus for this purpose, is a glass tube, the size of which must depend on the quantity of matter to be decomposed. Having put the mixture at the bottom of it, it is to be heated, by which the arsenic in vapour rises, and is condensed the moment it comes in contact with the cold part of the tube, giving to it a dense metallic coating, resplendent like a mirror, next the glass, but of a grey colour, and with a crystalline appearance, on the inside *.

With the view of detecting arsenic in this way, it has been recommended to treat some of the residue of the evaporation in the manner described, by which it is presumed, that, if present, the glass will become coated; but this experiment seldom succeeds, because the vegetable and animal matter, undergoing decomposition, gives off gaseous fluids, which either carry away the arsenic, or diffuse it so much over the tube, that it is impossible to observe it; and hence we frequently fail in detecting it, though sufficient quantity is present to have given the metallic coating, were it not for the circumstance stated.

From what has been said, it is evident that little reliance can be placed in the modes of detecting arsenic now enumerated, for though the liquid tests may be used so as apparently to be free from fallacy, yet it may, and frequently does happen, that we do not get the precipitates of the proper colour, while by the dry experiments we may fail in detecting it though present. The tube experiment, it has been said, when it does succeed, is by far the best, and quite decisive of the presence of arsenic. All that is wanted, then, is to get quit of the obstacles

* The mode of preparing black flux has been described at p. 233. It is preferred to powder of charcoal, because, owing to its containing carbonate of potass, the arsenous acid is converted to arsenite, and is thus rendered fixed; so that the temperature may be raised sufficiently without any danger of driving it off before it is decomposed, which is generally the case when charcoal alone is used.

to its success, and which is done by using some of the precipitates instead of the residue of the evaporation, because the arsenic, if present, is then in a *state of concentration*, and is free in a great measure from animal and vegetable matter, which are the causes of failure. From all the precipitates arsenic can be obtained, but the reduction is most easily effected with the nitrate of silver ore, and with that by sulphuretted hydrogen.

Suppose then a fluid given with the view of ascertaining whether it contains arsenic; it is to be boiled, filtered if necessary, and solution of nitrate of silver added as long as it throws down a precipitate, after which it must be again filtered, and put in ammonia cautiously. If a precipitate of a yellowish colour is formed, it is probable that it is arsenite of silver, but to be certain that it really is so, it must be submitted to the process of reduction. For this purpose, having collected it on a filter, and dried it, it must be mixed with three or four times its bulk of black flux, placed in a glass tube of about 6 or 8 inches in length, and from 1-8th to 1-4th of an inch in width, and heated by means of a spirit lamp. Should any moisture be given off, it must be removed by means of a wire with a little tow, and the heat continued till the end of the tube becomes red, and if arsenic is present, it will rise in vapour, and be condensed on the cool part of the apparatus, giving the dense metallic coating, with a well defined edge next the mixture. To be satisfied that this is really arsenic, a part of it may be removed by a wire, and placed on a hot plate, by which it will rise in vapour, and give the alliaceous odour. Or if the coated part of the tube be held over the flame of a spirit lamp, the coating quickly flies off to another part, giving to it the same appearance. Another and perhaps still more decisive method is that recommended by Dr Turner, (papers by Dr Christison, Med. Chir. Tr. of Ed. ii.). After having freed the tube from moisture or other impurities, and closed the end of it, the coating is to be driven up and down by the heat of a lamp, by which, if it is arsenic, it will unite with oxigen, be converted to

oxid, and adhere to the glass in minute crystals, generally of an octohedral form *.

The precipitate by means of sulphuretted hydrogen may be treated in the same way, but different means are followed in procuring the precipitate itself. Some recommend that the fluid, after being boiled and filtered, should have a stream of sulphuretted hydrogen passed through it, having, however previously added a little acid, such as acetic, to neutralize any alkali that may be present, by which the action of the gas on the arsenic is prevented. (See Dr Christison's paper already referred to.) I prefer, however, the method already noticed in explaining the use of the tests in the liquid way, because we not only get the whole of the poison in solution, whether it be arsenous acid or sulphuret, but also remove other metallic matter, which might render the process more liable to failure. Having boiled the fluid, then, with potassa for some time, and filtered it while warm, a stream of sulphuretted hydrogen is passed through it when it has become cold, after which it must be again filtered, if necessary. To the filtered liquor diluted sulphuric or muriatic acid, or, which answers equally well, acetic acid, is to be added, and if a precipitate appears, it must, after collecting it, be submitted to the process of reduction as already described, using the precautions noticed, both as to the mode of conducting the experiment, and the necessity, provided the tube acquires a coating, of proving that it is an arsenical one.

* A spirit lamp is preferred as a means of applying heat, because the tube, when put into a chauffer, is apt to be melted, and allow the arsenic vapour to escape. Too great heat ought also to be avoided, because the glass, if it contain oxid of lead, which it generally does, is decomposed, the charcoal depriving the lead of its oxigen, and setting free metallic lead, gives to the tube an appearance, which by an unexperienced eye may be mistaken for arsenic. Instead of subjecting the precipitate to this process, it may be washed with muriatic acid, by which, if it is arsenite, the oxid of silver, will be deposited as a chlorid, and the arsenous acid will be left in solution; by evaporation to dryness, and heating the residue with black flux in the tube, it will give the coating.

If, in the contents of the stomach or alimentary canal, any white or yellowish particles be observed, they must be removed, placed in a glass with solution of potass, and boiled, by which, if it is arsenous acid, it will become arsenite; or if sulphuret, it will be dissolved. If the former, nitrate of silver and sulphuretted hydrogen, along with an acid, will throw down yellow precipitates; if the latter, all that is necessary, is to add an acid, by which the sulphuret will be deposited. To prove that these are arsenical precipitates, they must be submitted to the process of reduction.

With respect to the quantity of arsenic necessary to insure success, it has been mentioned, that 1-10th, nay, that less is sufficient, as from it the metallic coating can be easily procured; it has even been said, that from the 1-50th, or from the 1-100th of a grain, a decided crust is given to the tube, provided it is small enough; but this happens only when there is no other matter present. The case is altogether different when the arsenic is held in solution in the contents of the stomach; for though from it we may obtain precipitates, even though a very minute quantity is present, yet when we have to procure from these the metallic coating, we may fail, owing to the animal or vegetable matter which they may contain undergoing decomposition, and evolving gases, by which the arsenic, in its vaporific form, is carried out of the tube.

Detection of Mercury.

The same remarks are applicable to the detection of mercury, as have been already offered when describing the modes of detecting arsenic. Tests have been recommended, which, provided we are working on a transparent colourless fluid, are extremely delicate; but in this, as in other cases of poison, we must lay our account with operating on a fluid, not only coloured, but containing different ingredients, which may affect the tests; and hence the necessity of not being satisfied with the results of our experiments, unless we actually procure mercury in its metallic state.

The mercurial compound, administered as a poison, is corrosive sublimate, which being soluble, must, of course, be looked for in the fluid contents of the stomach, or upper part of the intestinal canal.

Muriate of mercury is decomposed by alkalies and earths, but the colour of the precipitates differs. That with potassa and soda is of a brick-red colour, while that with ammonia is white; the former being a hydrated oxid, the latter a triple ammoniaco-muriate, (p. 59.) Sulphuretted hydrogen, when passed through solution of the muriate, gives a black precipitate, and the same also happens with a hydro-sulphuret. Muriate of mercury may also be decomposed by the immersion of gold, if a galvanic action be also excited, as by touching it with a piece of zinc or iron, by which it is amalgamated at the points of contact; but though all of these answer well for indicating the presence of mercury in common instances of analysis, the necessity of procuring it in its metallic state, in cases of poisoning, must be obvious.

Though the alkalies and earths are not to be considered as tests of mercury, yet, by decomposing the muriate, they afford a means of procuring precipitates, from which we can obtain mercury in its metallic form, by the common process of reduction. Suppose, then, we wish to ascertain if, in the contents of the stomach, there is any corrosive sublimate, the fluid must be boiled and filtered, and to the filtered liquor, solution of potassa, of soda, or of ammonia added. If a precipitate is formed, it must be collected on a filter washed and dried in the usual way *; and after being mixed with three or four times its bulk of black flux, and placed in a tube, it is to be heated by a spirit lamp. If mercury is present, it will rise in vapour, and be condensed in minute globules on the cool part of it, the carbon removing the oxigen, and leaving the mercury in its metallic state.

* The precipitates formed by potassa and soda merely lose their moisture, but that by ammonia gives off also muriate of ammonia, and becomes oxid; so that they are all of the same nature after being dried.

If any white particles be observed adhering to the coats of the stomach, it can be proved whether they are corrosive muriate, by dissolving them in water, and treating the solution as already described.

If *Calomel* has been administered, as it is insoluble, it is likely to be found adhering to the coats of the stomach. Perhaps the best mode of proving that the powder, in this case, contains mercury, is to remove it from the surrounding medium, wash it with a little water, and then pour some solution of potassa on it, by which it is instantly changed to black oxid, (p. 53.) After having washed and dried it, it is to be heated with black flux in a tube, by which globules of mercury will appear.

Detection of Lead.

Though lead is very easily detected in common cases of analysis, yet, as we do not obtain the precipitates of their proper colour when operating on the contents of the stomach, we must have recourse to the process of reduction, to be satisfied that lead is present. The compound of lead administered as a poison, is the acetate, which is decomposed by sulphuretted hydrogen, and by hydro-sulphurets, and also by sulphuric acid and sulphates, the former yielding a black, the latter a white precipitate; the one a sulphuret, the other a sulphate, both of which are decomposed by heat and charcoal, the sulphur from the first, and the acid and oxigen from the last, being driven off, so that metallic lead is left.

With the view, then, of ascertaining whether the fluid contains lead, having boiled and filtered it, a solution of any hydro-sulphuret, or of a sulphate, is to be added; and if a precipitate is formed, it must be collected in the usual way, and dried, but removing it from the heat before the whole of the moisture is expelled. It is then to be placed in a little cavity made in charcoal, and kept before the flame of a blow-pipe for some time, applying the heat cautiously at first. If it contain lead, a globule of it will be gradually formed and collected in the cavity.

That it is lead, may be known by its being easily cut, by its being soluble in nitric acid, and its solution yielding a black precipitate with hydro-sulphurets, and a white one with sulphates; but there is scarcely any necessity for having recourse to this, as the appearance of the globule, when cut, is quite characteristic.

Detection of Oxalic Acid.

The detection of vegetable poisons is equally difficult with that of the mineral ones; for though we have very delicate tests of them when they exist in a transparent colourless solution; yet, as the colouring matter, and other substances in the contents of the stomach, alter the appearance of the precipitates, it is evident that we must have more decisive proofs of their presence.

When oxalic acid has been swallowed, as it is soluble, it is of course to be looked for in the fluid contents of the stomach; so that with the view of detecting it, having first tried whether there is any free acid, the liquor must be boiled with sub-carbonate of potass, by which the acid is converted to oxalate, and becomes much more soluble. It is then to be filtered when warm, and should there be any excess of alkali, it must be neutralized by acetic acid, after which solution of muriate of lime is to be added, by which, if oxalate is present, a whitish precipitate will fall. To be satisfied that this contains oxalic acid, it must, after being washed and collected in the usual way, be boiled with carbonate of potass, then filtered, and any excess of alkali in the filtered liquor saturated as before with acetic acid. If the solution contains oxalate, it will give a white precipitate with lime water. It will yield precipitates also with metallic salts, those of zinc, tin, lead, and manganese being white, of copper and nickel bluish green; but perhaps the most decisive test is the decomposition by means of nitrate of silver, and formation of a white precipitate, known to be oxalate, by putting a little of it, properly washed and dried, on a piece of platinum foil, and hold-

ing it over a spirit lamp, by which it detonates, though feebly. (Christison on Poisoning by Oxalic Acid.)

Detection of Hydro-cyanic Acid.

When hydro-cyanic acid has been swallowed, the contents of the stomach have, in general, the peculiar odour of bitter almonds, or of laurel leaves, and the acid can be detected in it by the addition of re-agents. If, for instance, to the liquor, boiled with aqua potassæ, and filtered, a few drops of solution of sulphate of iron be added, having previously neutralized the excess of alkali by any acid, Prussian blue is instantly deposited. It may be difficult, however, nay, perhaps impossible, to judge of the colour of the precipitate; so that in this case we must have recourse to more decisive tests. If the precipitate, after being washed and collected in the usual way, be boiled with aqua potassæ, it will, if it is Prussian blue, yield a solution of ferro-cyanate of potass, (p. 15.) which can be proved to be so by the addition of sulphate of iron, having previously neutralized excess of alkali. For these experiments, solution of per-sulphate of iron (the proto-sulphate long exposed to air) must be used.

Another and equally decisive test, is to agitate the filtered contents of the stomach, but without adding alkali, along with red oxid of mercury, by which hydro-cyanate of mercury is formed, and which, when evaporated to dryness, will yield cyanogen gas by the application of heat. For this purpose, the evaporated residue being carefully dried, must be put into a small tube, on the open end of which the fore-finger is held. Heat is then to be applied by means of a spirit lamp, by which, if it be cyanuret, mercury will rise in vapour, and be condensed in globules, and the tube will be filled with cyanogen gas. This may be known by its odour, but more particularly by applying the mouth to the lamp, by which the gas will be observed to burn with the rose red flame peculiar to it. This experiment, with pure cyanuret,

will succeed with 1-4th of a grain, but as we are not to expect the residue of the evaporation to be pure, a grain will, perhaps, in most cases be necessary.

If the contents of the stomach are likely to yield much animal and vegetable matter by evaporation, instead of following the process described, it will be better to decompose the precipitate thrown down by sulphate of iron; for which purpose, it must be boiled with red oxid of mercury, and the solution, after filtration, evaporated to dryness, (p. 18.) The residue is then to be heated in the tube, to try to get cyanogen from it.

Instead of adding tests to the contents of the stomach, Lassaigne (An. de Chem. xxvii.) has proposed to subject it to distillation, by which, if free hydro-cyanic acid is present, it will come off in vapour, and be condensed in the receiver along with water; and as the product is colourless, it will, on the addition of the salt of iron, yield the precipitate of the proper blue colour. This mode of detecting hydro-cyanic acid, answers well, unless it has combined with free alkali in the contents of the stomach, in which case it is necessary to add an acid to decompose its salt, and set it at liberty.

The result of the iron test may be confirmed by agitating the distilled liquor with red oxid of mercury, and trying to get cyanogen gas from it, after evaporation to dryness, as already described.

The analysis of a fluid, with the view of detecting hydro cyanic acid, should be performed as soon as possible, because it quickly undergoes decomposition when in contact with putrefying animal or vegetable matter. Lassaigne failed in detecting it in the contents of the stomach of a rabbit, a few days after it was poisoned by it.

Detection of Opium.

Though opium may in general be detected by its smell, it can also be indicated in solution by the addition of re-agents. It has been already mentioned, (p. 248.

251.) that there exist in opium both meconic acid and morphia; and as the former is precipitated by metallic salts, we have thus a means of showing its presence, and also that of opium. The most delicate test is that pointed out by Dr Hare, (Silliman's Journ. xii.) It consists in adding acetate of lead to the fluid suspected to contain opium, by which meconate of lead is deposited. Having poured off the supernatant liquor, and washed the precipitate, a few drops of sulphuric acid, and immediately afterwards, about as much of the solution of red sulphate of iron, must be poured on it, by which the meconic acid is set at liberty, and, acting on the iron, communicates to it a deep red colour. According to Hare, opium can thus be detected in a fluid composed of ten drops of laudanum and half a gallon of water.

If, instead of a salt of iron, sulphate of copper be used, the fluid becomes emerald green.

Assay of Potashes, Kelp, and Barilla.

These substances are prized for the quantity of alkali they contain, either free, or in union with carbonic acid, or sulphuretted hydrogen. As sulphuric acid will unite with the potass in the first, and with the soda in the two last, the quantity of this they require for neutralization affords an easy method of finding their value. For this purpose, it is first necessary to prepare an acid of *known strength*, that is, one the quantity of real sulphuric acid in which is known. This is done by diluting it with water, and after it has cooled, taking its specific gravity. The table given in the Appendix, will show how much real acid 100 parts by weight contain. Thus, 100 grains of acid, of specific gravity 1141, contain 16.31 of real acid. Now, as 100 grains of real acid unite with 120 of potassa, and with 80 of soda, we have merely to take a certain quantity of the article, and having dissolved it, try how much of the diluted acid it will take to saturate its alkali. Thus, let 100 grains be dissolved in water

by boiling, filter the solution, and pour on boiling water on the filter, till the whole of the soluble matter is taken off, which is known by its not making litmus paper blue as it comes through; next take a measure graduated so as to hold 100 grains by weight, and having filled it with acid, add it drop by drop to the solution, till the litmus paper becomes red, which will shew that there is an excess of acid, in other words, that the whole of the alkali has been saturated.

Suppose that the acid is of sp. gr. 1141, containing, as the table shows, 16.31 of real acid, and that the 100 grains of the article have taken 97 for saturation, then,

as 100 : 16.31 : : 97 : 15.82;

and as 100 of acid combine with 120 of potass, then,

as 100 : 120 : : 15.82 : 18.98;

so that the 100 grains of the article contain 18.98 of potassa.

The same method must be followed with kelp and barilla. Suppose that 100 grains have taken 54 of diluted acid, then

100 : 16.31 : : 54 : 88;

and as 100 of acid unite with 80 of soda, then,

as 100 : 80 : : 88 : 7.04;

so that 100 grains would contain 7.04 of soda.

Another method of experimenting, and attended with much less trouble, by which we are more likely to find the *average* quantity of alkali, is to put 2000 grains of the article into a flask with 12 oz. of boiling water, and cork tightly. By leaving them together for three or four days, shaking frequently, the whole of the soluble matter is dissolved, so that, if 6 oz. be filtered off, we get the solution of 1000 grains, which may be tried with the acid, as already described.

Though by this mode of conducting the experiment, there must be a difference in the bulk of the fluid, owing to the diminution of temperature, yet the addition of the alkaline matter causes a slight enlargement, so that the one nearly counteracts the other; and hence, by taking at a natural temperature half the measure of the li-

quid used at 212, we get as nearly as possible, and sufficiently accurately for manufacturing purposes, the solution of half of the article employed.

In analysing these substances, as they vary much in their composition, it is necessary to select pieces from different parts of the cargo, all of which should be ground to powder, and the requisite quantity taken from this.

Particular attention must also be paid to the reddening of the litmus paper, because it is affected by the carbonic acid, or sulphuretted hydrogen disengaged from the alkali by the addition of the sulphuric acid; so that we may suppose we have reached the point of saturation, whereas the reddening may be occasioned by the gases. This is, however, easily known by holding the paper before a fire; if it be reddened by them, the original colour of the litmus returns, because they are expelled; but if it be by sulphuric acid, it is permanent; we must therefore add acid till the red does not disappear by heat.

As kelp and barilla contain alkali in union with sulphuretted hydrogen, it has been proposed by Gay Lussac, (An. de Ch. xiii.) to convert the latter into sulphuric acid, by mixing the solution with chlorate of potass, evaporating to dryness, and exposing the residue to a red heat. This method is, however, seldom practised, the other being sufficiently accurate for manufacturing purposes.

Assay of Limestone.

As the different kinds of limestone vary considerably in their composition, it is of the utmost consequence to ascertain the quantity of lime, which is done by a very simple process.

Put about an ounce of muriatic acid, diluted with about an equal quantity of water into a flask, and equipoise it; then take 100 grains of the limestone, reduced to small pieces, and having placed the flask on its side, put in a few of the fragments, and when they are dis-

solved, throw in more, and in this way continue the addition till the whole is used. The carbonic acid will be thus expelled, so that by knowing how much is given off, we find the quantity of lime. For this purpose, after the effervescence is ceased, blow into the flask with bellows, to remove the whole of the gas, and again weigh, keeping the original equipoise, and the 100 grains in the opposite scale. The loss of weight is the carbonic acid, and which must have been in union with the lime. Now, carbonate of lime is composed of 46 of acid, and 56 of lime; so that, by the rule of proportion, we find the quantity of lime. Thus, suppose 100 grains of the limestone have lost 23 of acid, then,

as 44 : 56 : : 23 : 33.8,

so that it contains 33.8 per cent. of lime.

Though this process is extremely simple, and when the limestone is pure, is sufficiently accurate, yet it is not altogether free from fallacy. Limestone occasionally contains carbonate of magnesia, in which case the acid gas evolved does not give the quantity of lime. It may be necessary, therefore, to ascertain whether magnesia is present. Magnesian limestones are distinguished from common limestones, by the difference in the action of acids, the former being dissolved very slowly, the latter, even the most indurated of them, quickly. But a more certain method is to apply tests to the solution; and for this purpose, having, after neutralizing excess of acid, removed the lime by oxalate of ammonia, add to the filtered fluid carbonate of ammonia and phosphate of soda, by which, if magnesia is present, the ammoniaco-magnesian phosphate will be formed. Should the limestone contain magnesia, the proportion of the earths is ascertained, by dissolving 100 grains in muriatic acid, neutralizing the excess of acid after filtration, and precipitating, as above mentioned; indeed, the process to be followed is the same as has been described under mineral waters, (p. 430.) the quantity of lime being found by the formation of oxalate, and of magnesia by the magnesian phosphate.

ADDENDUM.

BROMINE.

M. Balard, an apothecary at Montpellier, while engaged in experiments on sea water, discovered in it a peculiar substance, to which he gave the name of *muride*, but which was afterwards changed to *brome*, or, according to the English nomenclature, *bromine*, (βρωμος, *strong smelling.*)

He is inclined to consider it a simple substance; but as its title to be ranked in this class has not yet been satisfactorily established, I did not deem it proper to introduce it among them.

Bromine is procured from sea water, and for this purpose *bittern* is used. When it is treated with chlorine, it assumes an orange yellow tinge, and on the application of heat, reddish vapours of bromine come off, which may be condensed in a proper apparatus. A better method of obtaining it, is, after passing a stream of chlorine gas through the fluid, to shake it with ether, which, by its dissolving the bromine, acquires a hyacinth red colour. The solution is then agitated with that of potassa, by which the bromine, decomposing the water, seizes its hydrogen, becomes an acid, and unites with the alkali, and will, on evaporation, yield crystals. When these are mixed with black oxid of manganese, and sulphuric acid, diluted with half its weight of water, and subjected to distillation, a vapour comes off, which may be condensed, either in a cool receiver, or in cold water; and to free it from any adhering moisture, it must be again dis-

tilled, the vapour being passed over dried muriate of lime. If in this case we consider the crystals similar in their nature to chloruret of sodium, then the action by which the bromine is evolved, is the same as when chlorine gas is prepared by means of a mixture of sea salt, black oxid of manganese, and sulphuric acid,—the oxigen of the oxid uniting with the potassium, and liberating the bromine.

Bromine, at a natural temperature, is a liquid of a blackish red colour when viewed by reflected, but hyacinth red by transmitted light. It has an odour similar to that of chlorine, and like it acts powerfully on the animal system, and has the property of destroying colour. Its specific gravity is about 3000. It is very volatile, passing off in reddish coloured vapour, even at a natural temperature; at a degree or two below zero, it becomes a hard brittle solid. Its boiling point is 116.5. It is not affected by heat, by light, or by electricity. It is soluble in water, yielding a solution of a reddish colour.

Bromine unites with oxigen and with hydrogen, forming acids called *bromic* and *hydro-bromic*. When its ethereal solution is shaken with potassa, there is a decomposition of the water, its ingredients being transferred to the bromine to form the acids, with which the alkali unites, and *bromate* and *hydro-bromate* of potass are the result.

Bromic acid may be obtained in its separate state, by the addition of sulphuric acid to bromate of baryta. In many of its properties, it resembles chloric acid.

Bromine does not unite with hydrogen at a natural temperature, but on introducing a lighted taper or a red hot wire, they enter into union without explosion, and generate the acid. They may also be made to combine, by introducing the bromine into a gaseous fluid containing hydrogen, as sulphuretted and phosphuretted hydrogen, or hydriodic acid; but the easiest mode of obtaining hydro-bromic acid, is to heat a mixture of bromine and phosphorus moistened, by which a gaseous fluid is given off, that must be collected over mercury. As thus

obtained, it is a transparent colourless gas, having an acid taste, and being extremely irritating to the fauces. It is not affected by heat nor by light. When passed through incandescent tubes, along with oxigen, it is not altered. It is decomposed, however, by chlorine, which deprives it of its hydrogen to form muriatic acid, and sets the bromine free. Hydro-bromic acid is rapidly absorbed by water, affording a transparent colourless solution, having an acid taste. Like the gas, it is decomposed by chlorine. It is acted on also by other acids, the action with nitric acid being peculiar, as by means of it a fluid is obtained, similar in its properties to aqua regia, having the power of dissolving gold.

The composition of hydro-bromic acid gas is proved by its action with potassium, which, when kept in contact with it, unites with the bromine, and hydrogen, equal to half the volume of the gas, is evolved.

Bromine unites with chlorine, and forms a fluid of a reddish yellow colour, having a disagreeable odour and taste. It is soluble in water, the solution possessing the characteristic feature of the simple substances, that of destroying colour. When treated with alkaline fluids, there is decomposition, both of the chloruret and of the water, for muriatic and bromic acids are produced.

Bromine unites also with phosphorus, sulphur, and iodine, and with olefiant gas it generates an oily-looking fluid, analogous in its nature to that produced with chlorine by the same gas, so that it is probably a bromuret of carbon.

Bromine unites also with cyanogen, and forms a poisonous compound. It may be prepared, according to Serullas, by putting bromine and cyanuret of mercury together, into a tube surrounded by a freezing mixture; heat is disengaged, and bromuret of mercury and cyanuret of bromine are formed, and may be separated by sublimation, the latter passing off in vapour, and condensing in slender crystals. It is soluble in water and in alcohol, and with alkaline fluids generates hydro-bromates and hydro-cyanates. A grain dissolved

in water, and introduced into the esophagus of a rabbit, caused instant death.

The action of bromine with the metals, is in many respects similar to that of chlorine and iodine. When, for instance, potassium is put into it, there is a disengagement of heat and light, and the action becomes so violent as to render the experiment dangerous, unless performed in minute quantities. When antimony and tin also are thrown into it, they are instantly inflamed. The compounds formed, called *bromids* or *bromurets*, are analogous to chlorurets; for, according to Balard, they are converted by water to hydro-bromates. They are decomposed by chlorine, which unites with the base, and sets the bromine free.

Bromine acts also with salifiable bases, in the same way as chlorine and iodine. When its vapour is passed over the fixed alkalies, lime, or baryta, they become incandescent, oxigen is disengaged, and bromuret of the metallic base is formed; but when the alkali or earth is in solution, there is, as already stated, the decomposition of the water, and the production of bromate and hydro-bromate, the former analogous to chlorates and iodates, the latter to muriates.

Bromate of potassa is, like chlorate, decomposed by heat, yielding oxigen and bromuret of potassium. It deflagrates when thrown on live coals, and with sulphur forms an explosive mixture. It is decomposed also by acids, and like chlorate, though its acid is liberated, it undergoes decomposition. From bromate of baryta, however, the acid may, as already stated, be obtained undecomposed.

The hydro-bromates of the alkalies and of the alkaline earths are soluble, and are similar in many respects to muriates, their solutions, according to Balard, yielding bromurets, when evaporated to dryness. When chlorine gas is passed through them, owing to its powerful affinity for hydrogen, muriates are formed, and bromine set at liberty. Some of the metallic salts are decomposed by hydro-bromates, and precipitates are formed, which

are considered bromurets; thus, nitrates of lead, silver, and mercury, the last in the state of proto-nitrate, yield white powders, that with silver being in appearance and properties similar to the chlorid, and that with mercury analogous to calomel.

Bromine is soluble in alcohol and in ether, from which it is procured by evaporation.

Bromine, according to Balard, exists in sea water, in the state of hydro-bromate of magnesia; so that on the addition of chlorine, its acid is decomposed, muriatic acid being formed, and bromine disengaged; and hence the process for procuring it. He has detected it also in the marine plants growing on the shores of the Mediterranean, and in the sea weeds employed for yielding kelp. It exists also in the animal kingdom, at least those of maritime production, as the *Janthina Violacea*, which belongs to the testaceous Mollusca.

Should it be hereafter proved that bromine is really a simple substance, it must be placed in the same class with chlorine and iodine, to which, in fact, it bears a very strong resemblance, being acidifiable both by oxigen and hydrogen, and forming compounds, convertible by water into salts. For a full account of the properties of bromine, the reader is referred to the original paper of Balard, in the An. de Ch. xxxii.; a paper by Liebeg, An. de Ch. xxxiii.; and another by Serullas, An. de Ch. xxxiv.

It may be proper to state, that though the above-mentioned chemists consider bromine to be a distinct simple substance, Chevreuil has announced to the Academy of Sciences at Paris, that he has prepared a *chlorid of iodine*, possessing all the properties ascribed to it. (Bull. Univers. c. ix. 277.)

APPENDIX.

SPECIFIC GRAVITY.

By *Gravity* is meant that power by which bodies are made to approach this earth. All substances, when left to themselves, descend; but this takes place differently in different instances,—in other words, substances are of different weights. Thus, a piece of gold is heavier than one of silver of the *same size;* and a piece of silver weighs more than the same bulk of wood. Though similar bulks of bodies are of different weights, yet the same *quantity of matter* in all, is drawn towards the earth with the same force; it must therefore be of equal weight. If equal bulks of bodies, then, are of different weights, they must contain different quantities of matter; and this has given rise to the term *Specific Gravity*, by which we are to understand the comparative weights of equal bulks of different substances, or their comparative quantities of matter. Thus, if we have a piece of wood and of lead of the same weight, they will be of different sizes; they are therefore of different specific gravity, because the one has less matter than the other in the same volume; that which has least is of the least specific gravity.

When equal bulks of bodies, then, contain the same

matter, that is, are of the same weight, they are of the same specific gravity. If they have different quantities of matter, or weigh differently, their specific gravity is different. The reverse of this is of course true. Those bodies, the specific gravity of which is the same, have, bulk for bulk, the same, while those, the specific gravity of which differs, have different quantities of matter.

As specific gravity means the comparative quantities of matter in bodies, it is necessary to have one as a standard of comparison. For this purpose, water has been fixed on, and called 1000. If, then, that of any substance be 3000, it denotes that it contains three times the quantity of matter, or is thrice as heavy as the same bulk of water. Or, it may be expressed in another way, to have the same weights of water and of this body, we must have three times as much by measure of the former as we have of the latter.

To ascertain the specific gravity of fluids, it is merely necessary to procure equal bulks of them, and weigh them. For this purpose, we take a small bottle, to which a stopper, having a groove in its side, or a hole through it, is accurately fitted. Having got an equipoise for both, the bottle is first to be filled with distilled water, dried, and weighed; suppose it hold exactly 1000 grains. To try the specific gravity of any fluid, say oil of vitriol, we have, after emptying and drying the bottle carefully, to fill it, put in the stopper, and, using the precautions as before of drying it, to weigh; suppose it weighs 1850 grains. In this case, we have equal bulks of water, which is taken as the standard, and of oil of vitriol, the one weighing 1000, the other 1850; the specific gravity of the latter is therefore 1850, compared to the former as 1000. If the bottle do not hold 1000 grains, we can easily refer the specific gravity to that number. Thus, if it hold only 500 of water, it will contain only 925 of vitriol, so that, knowing the weight of the water and the fluid, we refer it to 1000, by the Rule of Proportion, putting the weight of the water and 1000 as the first and third proportions, and that

of the fluid for the second. Thus, supposing the bottle to contain 757 of water, 943 of a fluid, then,

as 757 : 943 : : 1000 : 1245.6;

so that 1245.6 is the specific gravity; it is therefore of no consequence what quantity the bottle holds.

When no great accuracy is required, other methods are practised. Perhaps the easiest of these is, to find it by the *Areometer*, so called from αραιος, signifying *rarity*, and μετρον,—a measure of rarity. This is merely a glass ball, full of air, with an upright stem, on which are marked numbers, at the depths to which it will sink in fluids, the specific gravity of which is denoted by these numbers. Thus, it will sink to W 1000 in distilled water, to 1850 in oil of vitriol. In finding the specific gravity by this instrument, we have merely to put it into the fluid, and mark the number to which it sinks. If we wish to be more accurate with this, it is necessary to have different instruments for different fluids, so that the divisions on the scale may be large.



Another easy method of finding the specific gravity of fluids, is by Lovi's Beads. These are merely small glass balls, with a little tail, having numbers on them corresponding with the density of the fluids in which they float. Thus, bead 1000 floats in distilled water, and 1850 in oil of vitriol. When we wish to find specific gravity by these, we put in bead after bead, till we get one to float, or till we get one to sink, and another to rise to the surface; the specific gravity is denoted by the number on the bead which floats; or it is intermediate to those on the one that sinks and the other that swims. Thus, if 1075 sinks, and 1074 floats, the specific gravity is 1074½.

The specific gravity of solids is referred to a standard the same as with fluids, and for this purpose water has been fixed on, and called 1000; but as it is impossible to procure *exactly* equal bulks of a solid and fluid, we

must resort to another method of finding their specific gravity. It is well known, that when a solid is thrown into a fluid, it displaces just its own volume. We have, therefore, to take a vessel, fill it with water, and weigh it. Having weighed the solid, put it into the water, and again weigh, either previously removing the solid, or putting in an equipoise for it in the opposite scale; the vessel must weigh less than before, by the water thrown out: this is equal to the volume of the solid. We have, therefore, the weights of equal volumes of the solid and water, and consequently their specific gravity. Thus, suppose we have a tumbler full of water, weighing 10,000 grains, the solid weighing 100 grains; after the solid is put in, the tumbler weighs 9970, the equipoise for it being kept in the other scale. The water displaced is 30, (10,000—9970=30) the solid is 100, these are their specific gravities; and as

30 : 100 : : 1000 : 3333;

3333 is the specific gravity of the solid, compared to water as 1000.

This method is practised only when no great degree of accuracy is required, because it is difficult to dry the tumbler without spilling a little of the fluid. Another, and by far the most accurate mode, is, to weigh the solid in air, and then in the fluid, to the specific gravity of which we wish to refer it. A substance weighs less in water than in air, by a weight equal to that of the water it displaces. This, it has been already said, is its own bulk. The difference between the weight in air and in water, then, is the weight of its own volume of water; so that by this we have the weights of equal volumes, and, of course, the specific gravity.

To find the specific gravity of a solid, weigh it in air; suppose it weighs 175 grains, then, tying a very fine thread or a hair around it, attach it to the scale, and plunge it into water, and again equipoise; suppose that it now weighs 149 grains, the difference is 26,—that is the weight of the water displaced. The specific gravities are, as 26 to 175, and

as 26 : 175 : : 1000 : 6730.

This method answers only for solids heavier than water. If they should be lighter, we can easily make them sink, by tying a heavy body to them; and provided we know how much water it will displace, we can find the specific gravity.

For this purpose, having weighed the solid, tie to it a heavy body, and weigh both in water; then subtract from the difference between the weight of both in air and water, the difference of the weight of the heavy body in air and water; the remainder is that of the light object. We have thus the weight of the water displaced by it, and, of course, its specific gravity.

Thus suppose heavy body in air, -	315
in water, -	200
difference, -	115
light body (cork) in air - -	5
both together in air, - -	320
in water, - -	182
difference, -	138
difference of heavy body, - -	115
light body, -	23

So that 5 of cork displace 23 of water. Then as

23 : 5 : : 1000 : 217;

217 is the specific gravity of cork, water being 1000.

Should the solid be soluble in water, we must have recourse to another fluid, as spirit of wine, or ether, or a saturated solution of the substance itself, the specific gravity of which must be previously determined. We can then refer it from it to water. Thus, if the specific gravity of a solid is twice as great as that of its own solution, and that of the solution is twice as great as that of water, the specific gravity of the solid must be four times that of water. Suppose that the solid weighs,

in air, - 357 grains
in its own solution, 275

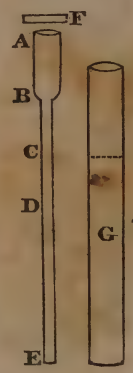
the difference is 82
then as 82 : 357 : : 1000 : 4353.

But we have previously found that the specific gravity of the solution is 1157 to water as 1000 ; then, as

1000 : 1157 : : 4353 : 5036.

5036 is the specific gravity of the solid, water being 1000.

Another method of finding the sp. gr. of solids, whether soluble or insoluble in water, or whether heavier or lighter than it, and which is particularly useful when the substance is porous, is that lately described by Professor Leslie. It consists in taking a glass tube A E, about three feet in length, open at both ends, the wide part A B, being about 4-10ths, the narrow part B E, 2-10ths of an inch in diameter, the one communicating with the other by a very fine slit at B, which will allow the passage of air, but not of any powder, and the upper opening being ground smooth, so that it can be stopped by a plate of glass F. The substance to be tried, being reduced to powder, is placed into A B, and the tube is then to be plunged into another one G, containing mercury,



till the fluid rises to the slit at B, after which the lid F is to be put on, and made air-tight. When in this state, the whole of the air, except that interspersed among the powder, is expelled, after which the tube must be raised, till the mercury stands in the inside at a height which, measured from the surface of that without, is half the length of the column of mercury in the barometer at the time. Suppose this is at C, the height being 15 inches, (Bar. suppose at 30,) then the air in the tube being under half its original pressure, will be doubled, so that A B will now contain only half as much as it did before the tube was elevated, the other half being in B C, which

is now of course equal *in volume* to what was in A B. After this, the lid being taken off, the tube is to be withdrawn, and having thrown out the powder, it is to be cleaned in the inside, and again put into the mercury; and the lid being replaced, it is raised till the mercurial column inside is 15 inches, by which the air in A B is doubled, and dilating occupies, suppose as far down as D, so that the space B D now holds the half of what A B did. In this experiment, the area of B C is equal to the whole air in A B while containing the powder, B D is equal to that of the air in A B without the powder, *the difference* C D must therefore be *equal to the volume of air expelled from* A B *by the powder*, *i. e.* it must be equal to the air of the same volume as the powder itself; so that by having on a graduated scale attached to the instrument, denoting the number of grains of water held by the narrow part of the tube, we find the quantity which any part of it will contain, and having weighed the solid, we thus get the weights of equal bulks of water and solid, and of course the specific gravity.

In fixing the specific gravity of gases, atmospheric air is taken as the standard, and called 1000.

The specific gravity of gases is determined in the same way as that of fluids, by weighing equal volumes of them; but it is necessary to have recourse to an air-pump to exhaust the vessel. For this purpose we take a flask with a stop-cock, which fits the screw of the pump. Having weighed it accurately, it is to be put on the pump, and exhausted, and again weighed. It must weigh less than before, by the air taken out. On applying it to a bladder filled with the gas, the specific gravity of which we wish to find, when the stop-cocks are opened, the gas flows in, so that if we again weigh, we get the weight of the gas. Here, then, we have the weights of equal volumes of air and gas, and, of course, their specific gravities. In performing this experiment, there is no necessity for exhausting the flask to the utmost, provided there is no action between the gas and air; for whatever be the quantity of air we take out, the same bulk of gas enters. Should the air

act chemically with the gas, we must remove the whole of it, and this is done by repeated exhaustions, filling the flask after each with the gas, so that after the last there is no atmospheric air. Suppose that the flask, when full of air, weighs 5750 grains, and after exhaustion 5738. Having introduced the gas, suppose it now weighs 5756.3, then 5750—5738=12, and 5756.3—5738=18.3, so that we have taken out 12 grains of air, but introduced 18.3 of gas; their specific gravities, as we have here the weights of equal volumes, are as 12 to 18.3, and

as 12 : 18.3 : : 1000 : 15.25,

which is the specific gravity, air being 1000.

As substances are liable to be affected by change of temperature, it is necessary of course to attend to this in taking specific gravity. In general 60 F. has been fixed on as a standard, so that, should the substances not be at this, it will be necessary to bring them to it; and this is of the utmost consequence with respect to gases, the alteration in volume being considerable, by slight changes of temperature. In finding the specific gravity of gases, we must attend also to the pressure of the atmosphere, and to their state of dryness. If they are not dry, or if the barometer is not at its standard, allowance must be made according to the formulæ given, vol. i. pp. 167, 194. If, however, the method recommended be adopted, of partially exhausting, and then immediately introducing the gas, there can, during the performance of the experiment, be no change in the pressure of the air, so as to affect materially the volume; so that there is no necessity for attending to it in taking specific gravity in this way.

Numerous other methods of finding specific gravity have been recommended, but what has been stated will, it is hoped, be sufficient to enable the reader to know what is meant by this term, and to illustrate the principle on which the processes for ascertaining it are conducted. The subject more properly belongs to mechanical philosophy, than to chemistry.

WEIGHTS AND MEASURES.

APOTHECARIES' WEIGHT.

Pound.	Ounces.	Drms.	Scruples.	Grains.	Grammes.
1 =	12 =	96 =	288 =	5760 =	372.96
	1 =	8 =	24 =	480 =	31.08
		1 =	3 =	60 =	3.885
			1 =	20 =	1.295
				1 =	0.06475

MEASURE LONDON PHARMACOPŒIA.

Gall.	Pints.	Ounces.	Drms.	Minims.	Troy Gr.	Cub. Inch.
1 =	8 =	128 =	1024 =	61440 =	58443	= 231.
	1 =	16 =	128 =	7680 =	7305	= 28.875
		1 =	8 =	480 =	456.5	= 1.8047
			1 =	60 =	57	= 0.2256
				1 =	0.9	= 0.0374

SCOTS LIQUID MEASURE.

Gall.	Quart.	Pint.	Choppin.	Mutchkin.	Gill.	Cub. Inch.
1 =	4 =	8 =	16 =	32 =	128 =	840
	1 =	2 =	4 =	8 =	32 =	210
		1 =	2 =	4 =	16 =	105
			1 =	2 =	8 =	52.5
				1 =	4 =	26.25
					1 =	6.56

The English ale gallon contains 277.3 cubic inches, the cubic inch of water weighing at 62 F. 252.72 Parliamentary grains. The English wine pint contains 28.875 cubic inches. The English wine gallon contains 231 cubic inches. The imperial gallon is 1-60th less than the ale gallon, and 1-5th more than the wine gallon.

NEW FRENCH MEASURES AND WEIGHTS.

MEASURES OF LENGTH.

The metre being at 32, and the foot at 62.

		Eng. Cub. Inch.		Eng. feet.		Inches.
Millimetre,	=	.03937				
Centimetre,	=	.39371				
Decimetre,	=	3.93710				
Metre *,	=	39.37100	=	3	=	3.371
Decametre,	=	393.71000				
Hecametre,	=	3937.10000				
Kilometre,	=	39371.00000				
Myriametre,	=	393710.00000				

MEASURES OF CAPACITY.

		Cub. Inches.		Eng. Wine Pint.
Millilitre,	=	.06103		
Centilitre,	=	.61028		
Decilitre,	=	6.10280	=	2.11353
Litre,	=	61.02800		
Decalitre,	=	610.28000		
Hecalitre,	=	6102.80000		
Kilolitre,	=	61028.00000		
Myrialitre,	=	610280.00000		

WEIGHT.

		Eng. Grains.		Troy Gr.
Milligramme,	=	.0154		
Centigramme,	=	.1544		
Decigramme,	=	1.5444		
Gramme,	=	15.4440	=	15.444
Decagramme,	=	154.4402		
Hecatogramme,	=	1544.4023		
Kilogramme,	=	15444.0234		
Myriagramme,	=	154440.2344		

* The Metre was found by Captain Kater to be 39.37079 inches, Ph. Tr. 1818. The length of a pendulum vibrating seconds in London, on the level of the sea, at 62 F. is 39.1393. Lond. Journ. xi.

TABLE of the Expansion of Solids, when heated from 32 to 212.

The figures denote the linear expansion, so that by multiplying the decimal ones by 3, the total expansion will be got. The table is constructed from the experiments of Lavoisier and Laplace, (Biot's Traité de Physique,) Smeaton, (Ph. Tr. 1784.) Roy, and others.

Substances tried.	Dilatation in Decimals, the original length being 1.	Substances tried.	Dilatation in Decimals, the original length being 1.
Antimony -	1.00108300	Iron wire -	1.00123504
Bismuth -	1.00139200	Lead -	1.00284836
Brass -	1.00186671	Ditto -	1.00286700
—— cast -	1.00187500	Pewter, fine -	1.002283
—— wire -	1.00193000	Palladium -	1.0010000
—— 16, tin 1 -	1.00190800	Platinum -	1.00099180
Copper -	1.00172244	Ditto -	1.00085655
——— hammered	1.00170000	Ditto -	1.0038420
——— -	1.00171821	Silver, Paris standard	1.00190868
Glass tube without lead	1.00087572	Ditto -	1.0020826
——— with barom.	1.00083000	Solder, soft white lead 2, tin 1	1.0025080
——— -	1.00077615	—— spelter brass 2, zinc 1	1.0020580
—— rod -	1.00080787	Speculum metal -	1.00193300
—— English flint	1.00081166	Steel, hard -	1.00107875
—— crown -	1.00089760	—— ditto -	1.00122500
—— tube -	1.00086130	—— soft -	1.00107956
Gold, Paris standard not softened -	1.00155155	—— tempered -	1.00123956
—— pure -	1.00146606	Tin, Falmouth -	1.00217298
Iron -	1.00125800	—— Malacca -	1.00193765
Ditto -	1.00118203	—— Grain -	1.00248300
—— cast (prism) -	1.00110940	Zinc -	1.00294200
—— hammered -	1.00122045		

TABLE of the Expansion of Liquids from 32 to 212, their original bulk being 1.

Liquids.	Dilatation in Decimals.	Liquids.	Dilatation in Decimals.
Alcohol -	0.11000	Nitric acid (sp. gr. 1.40.)	0.11000
Fixed oils -	0.08000	Oil of turpentine	0.07000
Mercury -	0.02000	Sulphuric acid (sp. gr. 1.85.)	0.06000
Ditto -	0.01872	Sulphuric ether	0.07000
Ditto -	0.01852	Water -	0.04600
Ditto -	0.01680	Water saturated with common salt	0.05000
Ditto -	0.0180180		
Muriatic acid (sp. gr. 1.137.)	0.06000		

Table of the expansion of air from 32 *to* 212,—taking it for granted, that the expansion is 1-480th for each degree added. As all gases are equally expanded by equal additions of heat, of course the Table applies to all the bodies in this state.

Temp.	Bulk.	Temp.	Bulk.	Temp.	Bulk.
32°	1000000	59	1056249	86	1112499
33	1002083	60	1058333	87	1114583
34	1004166	61	1060416	88	1116666
35	1006249	62	1062499	89	1118749
36	1008333	63	1064583	90	1120833
37	1010416	64	1066666	91	1122916
38	1012499	65	1068749	92	1124999
39	1014583	66	1070833	93	1127083
40	1016666	67	1072916	94	1129166
41	1018749	68	1074999	95	1131249
42	1020833	69	1077083	96	1133333
43	1022916	70	1079166	97	1135416
44	1024759	71	1081249	98	1137499
45	1027083	72	1083333	99	1139583
46	1029166	73	1085416	100	1141666
47	1031249	74	1087499	110	1162499
48	1033333	75	1089383	120	1183333
49	1035416	76	1091666	130	1204166
50	1037499	77	1093749	140	1224999
51	1039583	78	1095833	150	1245833
52	1041666	79	1097916	160	1266666
53	1043749	80	1099999	170	1287499
54	1045833	81	1102083	180	1308333
55	1047916	82	1104166	190	1329166
56	1049999	83	1106249	200	1349999
57	1052083	84	1108333	210	1370833
58	1054166	85	1110416	212	1374999

TABLE of the Capacities of Bodies for Heat.

I. *Gases referred to Air as* 1.0000.

	Same bulk.	Same weight.
Air,	1.0000	1.0000
Hydrogen,	0.9033	12.3401
Carbonic acid,	1.2583	0.8280
Oxigen,	0.9765	0.8848
Azote,	1.0000	1.0318
Oxid of azote,	1.3503	0.8878
Olefiant gas,	1.5530	1.5768
Carbonic oxid,	1.0340	1.0805

II. *Gases referred to Water as* 1.0000.

	Same weight.		Same weight.
Water,	1.0000	Azote,	0.2754
Air,	0.2669	Oxid of azote,	0.2369
Hydrogen,	3.2936	Olefiant gas,	0.4207
Carbonic acid,	0.2210	Carbonic oxid,	0.2884
Oxigen,	0.2361	Aqueous vapour,	0.8470

III. *Fluids referred to Water as* 1.0000.

	sp. gr.		
Acid Nitric	(1200)	0.7600	
	(1298)	0.6613	
	(1300)	0.6600	
	(pale)	0.8440	
Muriatic	(1122)	0.6800	
	(1153)	0.6000	
Sulphuric	(1844)	0.3500	
Do. 4 + water 5		0.6631	
Do. 1 + do. 1		0.5200	
Acetic,	(1056)	0.6600	
Alcohol	(817)	0.6666	
	(853)	0.5897	
Ether sulph.	(729)	0.5432	
Oil of lintseed,		0.5280	
naphtha,		0.4151	
olives		0.5000	
spermaceti,		0.5000	
turpentine,		0.4720	
Spermaceti,		0.3990	

IV. *Solids referred to Water as* 1.0000.

Antimony,	0.0615	Lead,	0.0352
Bismuth,	0.0430	Mercury,	0.0357
Brass,	0.1123	Nickel,	0.1000
Copper,	0.1111	Platinum,	0.1300
Gold,	0.0500	Silver,	0.0820
Gun metal,	0.1100	Tin,	0.0704
Iron,	0.1269	Zinc,	0.0943
—— sheet,	0.1099		

TABLE of the Elastic Force of Aqueous Vapour, from 32 to 320, expressed in inches of Mercury.

Temp.	Dalton.	Ure.	Temp.	Dalton.	Ure.
32°	0.200	0.200	72°	0.770	
33	0.207		73	0.796	
34	0.214		74	0.823	
35	0.221		75	0.851	0.860
36	0.229		76	0.880	
37	0.237		77	0.910	
38	0.245		78	0.940	
39	0.254		79	0.971	
40	0.263	0.250	80	1.00	1.010
41	0.273		81	1.04	
42	0.283		82	1.07	
43	0.294		83	1.10	
44	0.305		84	1.14	
45	0.316		85	1.17	1.170
46	0.328		86	1.21	
47	0.339		87	1.24	
48	0.351		88	1.28	
49	0.363		89	1.32	
50	0.375	0.360	90	1.36	1.360
51	0.388		91	1.40	
52	0.401		92	1.44	
53	0.415		93	1.48	
54	0.429		94	1.53	
55	0.443	0.416	95	1.58	1.640
56	0.458		96	1.63	
57	0.474		97	1.68	
58	0.490		98	1.74	
59	0.507		99	1.80	
60	0.524	0.516	100	1.86	1.860
61	0.542		101	1.92	
62	0.560		102	1.98	
63	0.578		103	2.04	
64	0.597		104	2.11	
65	0.616	0.630	105	2.18	2.100
66	0.635		106	2.25	
67	0.655		107	2.32	
68	0.676		108	2.39	
69	0.698		109	2.46	
70	0.721	0.726	110	2.53	2.456
71	0.745		111	2.60	

Table continued.

Temp.	Dalton.	Ure.	Temp.	Dalton.	Ure.
112°	2.68		153	8.01	
113	2.76		154	8.20	
114	2.84		155	8.40	8.500
115	2.92	2.810	156	8.60	
116	3.00		157	8.81	
117	3.08		158	9.02	
118	3.16		159	9.24	
119	3.25		160	9.46	9.600
120	3.33	3.300	161	9.68	
121	3.42		162	9.91	
122	3.50		163	10.15	
123	3.59		164	10.41	
124	3.69		165	10.68	10.800
125	3.79	3.830	166	10.96	
126	3.89		167	11.25	
127	4.00		168	11.54	
128	4.11		169	11.83	
129	4.22		170	12.13	12.050
130	4.34	4.366	171	12.43	
131	4.47		172	12.73	
132	4.60		173	13.02	
133	4.73		174	13.32	
134	4.86		175	13.62	13.550
135	5.00	5.070	176	13.92	
136	5.14		177	14.22	
137	5.29		178	14.52	
138	5.44		179	14.83	
139	5.59		180	15.15	15.160
140	5.74	5.770	181	15.50	
141	5.90		182	15.86	
142	6.05		183	16.23	
143	6.21		184	16.61	
144	6.37		185	17.00	16.900
145	6.53	6.600	186	17.40	
146	6.70		187	17.80	
147	6.87		188	18.20	
148	7.05		189	18.60	
149	7.23		190	19.00	19.000
150	7.42	7.530	191	19.42	
151	7.61		192	19.86	
152	7.81		193	20.32	

Table continued.

Temp.	Dalton.	Ure.	Temp.	Dalton.	Ure.
194°	20.77		228	40.30	
195	21.22	21.100	229	41.02	
196	21.68		230	41.75	43.100
197	22.13		230.5		43.500
198	22.69		231	42.49	
199	23.16		232	43.24	
200	23.64	23.600	233	44.00	
201	24.12		234	44.78	
202	24.61		234.5		46.800
203	25.10		235	45.58	47.220
204	25.61		236	46.39	
205	26.13	25.900	237	47.20	
206	26.66		238	48.02	
207	27.20		238.5		50.30
208	27.74		239	48.84	
209	28.29		240	49.67	51.70
210	28.84	28.880	242		53.60
211	29.41		245	53.88	56.34
212	30.00	30.000	248.5		60.40
213	30.60		250	58.21	61.90
214	31.21		255	62.85	67.25
215	31.83		260	67.73	72.30
216	32.46		265	72.76	78.04
216.6		33.40	270	77.85	86.30
217	33.09		275	83.13	93.48
218	33.72		280	88.75	101.90
219	34.35		285	94.35	
220	34.99	35.540	285.2		112.20
221	35.63		290	100.12	120.15
221.6		36.700	293.4		
222	36.25		295	105.97	129.00
223	36.88		300	111.81	139.70
224	37.53		305	117.68	150.56
225	38.20	39.110	310	123.53	161.30
226	38.89		312		166.25
226.3		40.100	320	135.00	
227	39.59				

Table of the elastic Forces of the Vapours of Alcohol, Oil of Turpentine, and Petroleum or Naphthâ, in inches of Mercury. By Dr Ure. (Phil. Trans. 1818.)

Alcohol (sp. gr. 0.813.)		Alcohol (specific gravity 0.813.)		Petroleum.	
Temp.	Force of Vapour.	Temp.	Force of Vapour.	Temp.	Force of Vapour.
32	0.40°	193.3°	46.60°	316	30.00°
40	0.56	196.3	50.10	320	31.70
45	0.70	200	53.00	325	34.00
50	0.86	206	60.10	330	36.40
55	1.00	210	65.00	335	38.90
60	1.23	214	69.30	340	41.60
65	1.49	216	72.20	345	44.10
70	1.76	220	78.50	350	46.86
75	2.10	225	87.50	355	50.20
80	2.45	230	94.10	360	53.30
85	2.93	232	97.10	365	56.90
90	3.40	236	103.60	370	60.70
95	3.90	238	106.90	372	61.90
100	4.50	240	111.24	375	64.00
105	5.20	244	118.20		
110	6.00	247	122.10		
115	7.10	248	126.10		
120	8.10	249.7	131.40		
125	9.25	250	132.30		
130	10.60	252	138.60		
135	12.15	254.3	143.70		
140	13.90	258.6	151.60		
145	15.95	260	155.20		
150	18.00	262	161.40		
155	20.30	264	166.10		
160	22.60				
165	25.40				
170	28.30				
173	30.00				
178.3	33.50				
180	34.73				
182.3	36.40				
185.3	39.90				
190	43.20				

Oil of Turpentine.	
Temp.	Force.
304°	30.00°
307.6	32.60
310	33.50
315	35.20
320	37.06
322	37.80
326	40.20
330	42.10
336	45.00
340	47.30
343	49.40
347	51.70
350	53.80
354	56.60
357	58.70
360	60.80
362	62.40

TABLE of Frigorific Mixtures.

MIXTURES.	Thermometer sinks.	Deg. of cold produced.
Muriate of ammonia, - 5 parts Nitrate of potassa, - 5 Water, - - 16	From + 50° to + 10°	40
Muriate of ammonia, - 5 parts Nitrate of potassa, - 5 Sulphate of soda, - - 8 Water, - - 16	From + 50° to + 4°	46
Sulphate of soda, - 5 parts Diluted sulphuric acid, 4	From + 50° to + 3°	47
Sulphate of soda, - - 8 parts Muriatic acid, - - 5	From + 50 to 0°	50
Sulphate of soda, - 6 parts Muriate of ammonia, - 4 Nitrate of potassa, - 2 Diluted nitric acid, - 4	From + 50° to — 10°	60
Snow, or pounded ice, 2 parts Muriate of soda, - 1	From any Temperature. to — 5°	
Snow, or pounded ice, 5 parts Muriate of soda, - - 2 Muriate of ammonia, 1	From any Temperature. to — 12°	
Snow, or pounded ice, 24 parts Muriate of soda, - - 10 Muriate of ammonia, 5 Nitrate of potassa, - 5	From any Temperature. to — 18°	
Snow, - - - 3 parts Diluted sulphuric acid, 2	From + 32° to — 23°	55
Snow, - - - 8 parts Muriatic acid, - - 5	From + 32° to — 27°	59
Snow, - - - 7 parts Diluted nitric acid, - 4	From + 32° to — 30°	62
Snow, - - - 4 parts Muriate of lime, - 5	From + 32° to — 40°	72
Snow, - - - 2 parts Cryst. muriate of lime, 3	From + 32° to — 50°	82
Snow *, - - 3 parts Diluted nitric acid, - 2	From 0° to — 46°	46

* The materials for this, and the following mixtures, are to be cooled, previously to mixing, to the temperature required, by some of the preceding mixtures.

Table of Frigorific Mixtures—Continued.

MIXTURES.	Thermometer sinks.	Deg. of cold produced.
Snow, - - - 8 parts Diluted sulphuric acid, 3 Diluted nitric acid, - 3	From — 10° to — 56°	46
Snow, - - - 1 part Diluted sulphuric acid, 1	From — 20° to — 60°	40
Snow, - - - 3 parts Muriate of lime, - 4	From + 20° to — 48°	68
Snow, - - - 3 parts Muriate of lime, - 4	From + 10° to — 54°	64
Snow, - - - 2 parts Muriate of lime, - 3	From — 15° to — 68°	53
Snow, - - - 1 part Cryst. muriate of lime, 3	From — 40° to — 73°	33
Snow, - - - 8 parts Diluted sulphuric acid, 10	From — 68° to — 91°	23

TABLE of the Forces of Affinity.

OXIGEN.	Nitrogen Nickel Cobalt Copper Bismuth Mercury Silver Gold Platinum	Sulphur Carbon Phosphorus Nitrogen	CARBON.
Metallic bases of the alkalis and earths Carbon Manganese Zinc Iron Tin Antimony Hydrogen Phosphorus Sulphur Arsenic		NITROGEN.	Oxigen Iron Hydrogen
	HYDROGEN.	Oxigen Sulphur ? Phosphorus Hydrogen	SULPHUR.
	Oxigen		Iron Copper Tin Lead Silver

Table of the Forces of Affinity—Continued.

Bismuth	Magnesia	Lime	BENZOIC ACID.
Antimony	Glucina	Ammonia	
Mercury	Alumina	Magnesia	Potassa
Arsenic	Zirconia	Zirconia	Soda
Molybdena	Metallic oxides		Ammonia
	Silica		Baryta
			Lime
		ACETIC ACID.	Magnesia
NITRIC ACID.			Alumina
MURIATIC—*.	SULPHURIC ACID.	Baryta	
	PRUSSIC ‡.	Potassa	
Baryta		Soda	
Potassa	Baryta	Strontia	
Soda	Strontia	Lime	
Strontia	Potassa	Ammonia	POTASSA, SODA,
Lime	Soda	Magnesia	AND AMMONIA.
Magnesia	Lime	Metallic oxides	
Ammonia	Magnesia	Glucina	*Acids.*
Glucina	Ammonia	Alumina	Sulphuric
Alumina	Glucina		Nitric
Zirconia	Yttria		Muriatic
Metallic oxides	Alumina		Phosphoric
	Zirconia	OXALIC ACID.	Fluoric
	Metallic oxides	TARTARIC—	Oxalic
PHOSPHORIC ACID.		CITRIC—§.	Tartaric
CARBONIC †.			Arsenic
	SULPHU-RETTED HYDROGEN.	Lime	Succinic
		Baryta	Citric
Baryta		Strontia	Benzoic
Strontia		Magnesia	Sulphurous
Lime		Potassa	Acetic
Potassa	Baryta	Soda	Boracic
Soda	Potassa	Ammonia	Carbonic
Ammonia	Soda	Alumina	Prussic
		Metallic oxides	

* Ammonia should stand above magnesia.

† Magnesia should stand above ammonia, and alumina and silica should be omitted.

‡ With the omission of all after ammonia.

§ Zirconia after alumina.

Table of Simple Affinity—Continued.

LIME.			
Acids.	Acetic	Acetic	Arsenic
Oxalic	Boracic	Boracic	Fluoric
Sulphuric	Sulphurous	Sulphurous	Succinic
Tartaric	Carbonic	Carbonic	Citric
Succinic	Prussic	Prussic	Acetic
Phosphoric			Boracic
Nitric	STRONTIA.	ALUMINA.	Prussic
Muriatic			Carbonic
Suberic	*Acids.*	*Acids.*	
Fluoric	Sulphuric	Sulphuric	OXID OF COPPER.
Arsenic	Phosphoric	Nitric	
Citric	Oxalic	Muriatic	
Malic	Tartaric	Oxalic	Gallic acid
Benzoic	Fluoric	Arsenic	Oxalic
Acetic	Nitric	Fluoric	Tartaric
Boracic	Muriatic	Tartaric	Muriatic
Sulphurous	Succinic	Succinic	Sulphuric
Carbonic	Acetic	Citric	Nitric
Prussic	Arsenic	Phosphoric	Arsenic
	Boracic	Benzoic	Phosphoric
	Carbonic	Acetic	Succinic
		Boracic	Fluoric
BARYTA.		Sulphurous	Citric
		Carbonic	Acetic
Acids.	MAGNESIA.	Prussic	Boracic
Sulphuric			Prussic
Oxalic	*Acids.*		Carbonic
Succinic	Oxalic		
Fluoric	Phosphoric	OXID OF IRON.	
Phosphoric	Sulphuric		
Nitric	Fluoric	Gallic acid	OXID OF LEAD.
Muriatic	Arsenic	Oxalic	
Suberic	Succinic	Tartaric	Gallic acid
Fluoric	Nitric	Camphoric	Sulphuric
Arsenic	Muriatic	Sulphuric	Oxalic
Citric	Tartaric	Muriatic	Arsenic
Malic	Citric	Nitric	Tartaric
Benzoic	Benzoic	Phosphoric	Phosphoric

Table of Simple Affinity—Continued.

Muriatic Sulphurous Suberic Nitric Fluoric Citric Malic Succinic Acetic Benzoic Boracic Prussic Carbonic	Tartaric Phosphoric Citric Succinic Fluoric Arsenic Acetic Boracic Prussic Carbonic	Benzoic Oxalic Sulphuric Nitric Tartaric Phosphoric Citric Succinic Fluoric Arsenic Acetic Boracic Prussic	Muriatic Nitric Sulphuric Arsenic Fluoric Tartaric Phosphoric Oxalic Citric Acetic Succinic Prussic Carbonic
OXID OF TIN. Gallic acid Muriatic Sulphuric Oxalic Tartaric Arsenic Phosphoric Nitric Succinic Fluoric Citric Acetic Boracic Prussic	OXID OF MERCURY. Gallic acid Muriatic Oxalic Succinic Arsenic Phosphoric Sulphuric Tartaric Citric Malic Sulphurous Nitric Fluoric Acetic Benzoic Boracic Prussic Carbonic	OXID OF SILVER. Gallic acid Muriatic Oxalic Sulphuric Phosphoric Sulphurous Nitric Arsenic Fluoric Tartaric Citric Succinic Acetic Prussic Carbonic	ALCOHOL. Water Ether Volatile oils Alkaline sulphurets FIXED OILS. Lime Baryta Potassa Soda Magnesia Oxid of mercury Other metallic oxids Alumina
OXID OF ZINC. Gallic acid Oxalic Sulphuric Muriatic Nitric	OXID OF ANTIMONY. Gallic Acid Muriatic	OXID OF PLATINUM. GOLD *. Gallic acid	

* Omitting the oxalic, citric, succinic, and carbonic acids, and adding sulphuretted hydrogen after Prussic acid.

TABLE of the Quantity of Oil of Vitriol (sp. gr. 1.8485,) and of Real or Dry Sulphuric Acid in 100 Parts by Weight of diluted Acid of different sp. gr. By Dr Ure.—Lond. Journ. iv.

Liquid.	Sp. Gr.	Dry.	Liquid.	Sp. Gr.	Dry.	Liquid.	Sp. Gr.	Dry.
100	1.8485	81.54	66	1.5503	53.82	32	1.2334	26.09
99	1.8475	80.72	65	1.5390	53.00	31	1.2260	25.28
98	1.8460	79.90	64	1.5280	52.18	30	1.2184	24.46
97	1.8439	79.09	63	1.5170	51.37	29	1.2108	23.65
96	1.8410	78.28	62	1.5066	50.55	28	1.2032	22.83
95	1.8376	77.46	61	1.4960	49.74	27	1.1956	22.01
94	1.8336	76.65	60	1.4860	48.92	26	1.1876	21.20
93	1.8290	75.83	59	1.4760	48.11	25	1.1792	20.38
92	1.8233	75.02	58	1.4660	47.29	24	1.1706	19.57
91	1.8179	74.20	57	1.4560	46.48	23	1.1626	18.75
90	1.8115	73.39	56	1.4460	45.66	22	1.1549	17.94
89	1.8043	72.57	55	1.4360	44.85	21	1.1480	17.12
88	1.7962	71.75	54	1.4265	44.03	20	1.1410	16.31
87	1.7870	70.94	53	1.4170	43.22	19	1.1330	15.49
86	1.7774	70.12	52	1.4073	42.40	18	1.1246	14.68
85	1.7673	69.31	51	1.3977	41.58	17	1.1165	13.86
84	1.7570	68.49	50	1.3884	40.77	16	1.1090	13.05
83	1.7465	67.68	49	1.3788	39.95	15	1.1019	12.23
82	1.7360	66.86	48	1.3697	39.14	14	1.0953	11.41
81	1.7245	66.05	47	1.3612	38.32	13	1.0887	10.69
80	1.7120	65.23	46	1.3530	37.51	12	1.0809	9.78
79	1.6993	64.42	45	1.3440	36.69	11	1.0743	8.97
78	1.6870	63.60	44	1.3345	35.88	10	1.0682	8.15
77	1.6750	62.78	43	1.3255	35.06	9	1.0614	7.34
76	1.6630	61.97	42	1.3165	34.25	8	1.0544	6.52
75	1.6520	61.15	41	1.3080	33.43	7	1.0477	5.71
74	1.6415	60.34	40	1.2999	32.61	6	1.0405	4.89
73	1.6321	59.52	39	1.2913	31.80	5	1.0336	4.08
72	1.6204	58.71	38	1.2826	30.98	4	1.0268	3.26
71	1.6090	57.89	37	1.2740	30.17	3	1.0206	2.446
70	1.5975	57.08	36	1.2654	29.35	2	1.0140	1.63
69	1.5868	56.26	35	1.2572	28.54	1	1.0074	0.8154
68	1.5760	55.45	34	1.2490	27.72			
67	1.5648	54.63	33	1.2409	26.91			

TABLE of the quantity of real or dry Muriatic Acid, in 100 *parts of liquid acid, at different densities, by* Dr Ure. (An. of Phil. x.)

Specific Gravity.	Acid in 100.	Specific Gravity.	Acid in 100.	Specific Gravity.	Acid in 100.
1.1920	28.30	1.1272	18.68	1.0610	9.05
1.1900	28.02	1.1253	18.39	1.0590	8.77
1.1881	27.73	1.1233	18.11	1.0571	8.49
1.1863	27.45	1.1214	17.83	1.0552	8.21
1.1845	27.17	1.1194	17.55	1.0533	7.92
1.1827	26.88	1.1173	17.26	1.0514	7.64
1.1808	26.60	1.1155	16.98	1.0495	7.36
1.1790	26.32	1.1134	16.70	1.0477	7.07
1.1772	26.04	1.1115	16.41	1.0457	6.79
1.1753	25.75	1.1097	16.13	1.0438	6.51
1.1735	25.47	1.1077	15.85	1.0418	6.23
1.1715	25.19	1.1058	15.56	1.0399	5.94
1.1698	24.90	1.1037	15.28	1.0380	5.66
1.1679	24.62	1.1018	15.00	1.0361	5.38
1.1661	24.34	1.0999	14.72	1.0342	5.09
1.1642	24.05	1.0980	14.43	1.0324	4.81
1.1624	23.77	1.0960	14.15	1.0304	4.53
1.1605	23.49	1.0941	13.87	1.0285	4.24
1.1587	23.20	1.0922	13.58	1.0266	3.96
1.1568	22.92	1.0902	13.30	1.0247	3.68
1.1550	22.64	1.0883	13.02	1.0228	3.39
1.1531	22.36	1.0863	12.73	1.0209	3.11
1.1510	22.07	1.0844	12.45	1.0190	2.83
1.1491	21.79	1.0823	12.17	1.0171	2.55
1.1471	21.51	1.0805	11.88	1.0152	2.26
1.1452	21.22	1.0785	11.60	1.0133	1.98
1.1431	20.94	1.0765	11.32	1.0114	1.70
1.1410	20.66	1.0746	11.04	1.0095	1.41
1.1391	20.37	1.0727	10.75	1.0076	1.13
1.1371	20.09	1.0707	10.47	1.0056	0.85
1.1351	19.81	1.0688	10.19	1.0037	0.56
1.1332	19.53	1.0669	9.90	1.0019	0.28
1.1312	19.24	1.0649	9.62	1.0000	0.00
1.1293	18.96	1.0629	9.34		

TABLE of the Proportion of real Nitric Acid in 100 *Parts of the liquid Acid, at different Specific Gravities. By* DR URE.—London Journal, iv.

Specific Gravity.	Acid in 100.	Specific Gravity.	Acid in 100.	Specific Gravity.	Acid in 100.
1.5000	79.700	1.3783	52.602	1.1833	25.504
1.4980	78.903	1.3732	51.805	1.1770	24.707
1.4960	78.106	1.3681	51.068	1.1709	23.910
1.4940	77.309	1.3630	50.211	1.1648	23.113
1.4910	76.512	1.3579	49.414	1.1587	22.316
1.4880	75.715	1.3529	48.617	1.1526	21.519
1.4850	74.918	1.3477	47.820	1.1465	20.722
1.4820	74.121	1.3427	47.023	1.1403	19.925
1.4790	73.324	1.3376	46.226	1.1345	19.128
1.4760	72.527	1.3323	45.429	1.1286	18.331
1.4730	71.730	1.3270	44.632	1.1227	17.534
1.4700	70.933	1.3216	43.835	1.1168	16.737
1.4670	70.136	1.3163	43.038	1.1109	15.940
1.4640	69.339	1.3110	42.241	1.1051	15.143
1.4600	68.542	1.3056	41.444	1.0993	14.346
1.4570	67.745	1.3001	40.647	1.0935	13.549
1.4530	66.948	1.2947	39.850	1.0878	12.752
1.4500	66.155	1.2887	39.053	1.0821	11.955
1.4460	65.354	1.2826	38.256	1.0764	11.158
1.4424	64.557	1.2765	37.459	1.0708	10.361
1.4385	63.760	1.2705	36.662	1.0651	9.564
1.4346	62.963	1.2644	35.865	1.0595	8.767
1.4306	62.166	1.2583	35.068	1.0540	7.970
1.4269	61.369	1.2523	34.271	1.0485	7.173
1.4228	60.572	1.2462	33.474	1.0430	6.376
1.4189	59.775	1.2402	32.677	1.0375	5.579
1.4147	58.978	1.2341	31.880	1.0320	4.782
1.4107	58.181	1.2277	31.083	1.0267	3.985
1.4065	57.384	1.2212	30.286	1.0212	3.188
1.4023	56.584	1.2148	29.489	1.0159	2.391
1.3978	55.790	1.2084	28.692	1.0106	1.594
1.3945	54.993	1.2019	27.895	1.0053	0.797
1.3882	54.196	1.1958	27.098		
1.3833	53.399	1.1895	26.301		

TABLE of real Nitric in Acids of different Density. By Dr Thomson.—First Princ.

Atoms of Acid.	Atoms of Water.	Acid in 100.	Specific Gravities.
1	1	85.714	1.55
1	2	75.000	1.4855
1	3	66.668	1.4546
1	4	60.000	1.4237
1	5	54.545	1.3928
1	6	50.000	1.3692
1	7	46.260	1.3456
1	8	42.857	1.3220
1	9	40.000	1.3032
1	10	37.500	1.2844
1	11	35.294	1.2656
1	12	32.574	1.2495
1	13	31.579	1.2334
1	14	30.000	1.2173
1	15	28.571	1.2012

TABLE of the quantity of Alcohol (Sp. Gr. 796.) in 100 parts of fluids of different density at 60°. By Lovitz.

Sp. Gr.	Alc. in 100 pts.	Sp. Gr.	Alc. in 100 pts.	Sp. Gr.	Alc. in 100 pts.
796	100	838	84	875	68
798	99	840	83	879	67
801	98	843	82	880	66
804	97	846	81	883	65
807	96	848	80	886	64
809	95	851	79	889	63
812	94	853	78	891	62
815	93	855	77	893	61
817	92	857	76	896	60
820	91	860	75	898	59
822	90	863	74	900	58
825	89	865	73	903	57
827	88	867	72	904	56
830	87	870	71	906	55
832	86	871	70	908	54
835	85	874	69	910	53

Table continued.

Sp. Gr.	Alc.	Sp. Gr.	Alc.	Sp. Gr.	Alc.
912	52	939	40	962	28
915	51	941	39	963	27
917	50	943	38	965	26
920	49	945	37	967	25
922	48	947	36	968	24
924	47	949	35	970	23
926	46	951	34	972	22
928	45	953	33	973	21
930	44	955	32	974	20
933	43	957	31	975	19
935	42	958	30		
937	41	960	29		

TABLE of the quantity of Alcohol, sp. gr. .825 at 60 F. in various Wines, &c. By BRANDE.

	Proportion of Spirit per cent. by measure.		Proportion of Spirit per cent. by measure.
Lissa, average	25,41	Cape Madeira, aver.	20,51
Raisin wine, average	25,12	Grape wine	18,11
Marsala, average	25,09	Calcavella, average	18,65
Port, average	22,96	Vidonia	19,25
Madeira, average	22,27	Alba Flora	17,26
Currant wine	20,55	Malaga	17,26
Sherry, average	19,17	White Hermitage	17,43
Teneriffe	19,79	Rousillon, average	18,13
Colares	19,75	Claret, average	15,10
Lachryma Christi	19,70	Malmsey Madeira	16,40
Constantia, white	19,75	Lunel	15,52
Ditto, red	18,92	Sheraz	15,52
Lisbon	18,94	Syracuse	15,28
Malaga (1666)	18,94	Sauterne	14,22
Bucellas	18,49	Burgundy, average	14,57
Red Madeira, average	20,35	Hock, average	12,08
Cape Muschat	18,25	Nice	14,63

Table continued.

	Proportion of Spirit per cent. by measure.
Elder wine -	8,79
Cider, highest average	9,87
Barsac - -	13,86
Tent - -	13,30
Champagne, average	12,61
Red Hermitage -	12,32
Vin de Grave, aver.	13,37
Frontignac -	12,79
Côte Rotie -	12,32
Orange wine,—average of six samples made by a London manufacturer	11,26
Tokay - -	9,88
Ditto, lowest ditto	5,21
Perry, average of four samples -	7,26
Mead - -	7,32
Ale, average -	6,87
Brown stout -	6,80
London porter, aver.	4,20
Ditto small beer, ditto	1,28
Brandy - -	53,39
Rum - -	53,68
Gin - -	51,60
Scotch Whiskey	54,32
Irish ditto -	53,90

TABLE shewing the colour of the precipitates from metallic salts by Ferro-cyanate of Potass.

Metals.	Colour of Precipitates.	Metals.	Colour of Precipitates.
Antimony	White	Iridium	No precipitate.
Arsenic	White		
Bismuth	White	Iron { 1. Proto-salts	White, changing to blue.
Cadmium	White	Iron { 2. Per-salts	Deep blue.
Cerium	White	Lead	White
Chromium	Green	Manganese	White
Cobalt	Grass-green	Mercury	White, changing to yellow
Columbium	Olive	Molybdenum	Brown
Copper (per-salts)	Bright reddish brown	Nickel	Apple-green
Gold	White	Osmium	

Table continued.

Metals.	Colour of Precipitates.	Metals.	Colour of Precipitates.
Palladium	Deep Orange	Tellurium	No precipitate
Platinum	No precipitate	Tin	White
		Titanium	Reddish brown
		Tungsten	
Rhodium	No precipitate	Uranium	Blood-red
Silver	White	Zinc	White

TABLE shewing the proportion of the ingredients in an English Pint of some of the most important Mineral Waters.

Waters.	Temp.	Carb. Acid Gas. Cub. In	Sulph. Hyd. Gas. Cub. In	Nitrogen Gas. Cub. In	Carb. Hyd. Gas. Cub. In	Carb. Soda. Grains.	Carb. Lime.	Carb. Mag.	Sulph. Soda.	Sulph. Lime.	Sulph. Mag.	Sulph. Iron.	Mur. Soda.	Mur. Lime.	Mur. Mag.	Silica.	Oxid of Iron.	Total Saline Matter.
Pouges	50	30				10	1.2	12					2.2			0.5	2.5	28.4
Pyrmont	50	26					4.5	10		8.5	5.5		1.5				0.6	30.6
Spa	50	13				1.5	1.5	4.5					0.2				0.6	8.3
Seltzer	50	17				4	3	5					17.					29.
Harrogate, Old Well	69	.65	.8	.8	.58	1.84							92	8.9	5.4			108.14
New do.	60	.53	1.75	1.	.52	1.2							94	8.22	3.65			107.07
Aix la Chapelle	143		5.5			12.	4.75						5					21.75
Cheltenham	50	1.5	2.5						23.5	1.2	5		35				0.3	65.
Moffat	50	0.6	1.2	0.5									4.5					4.5
Brighton	50	2.5								4.09		1.8	1.53		0.75	.14		8.49
Harrogate, Oddie's	50					.84		.1		.23			37.5	2.75	1.23		.3	42.95
Seidlitz	50						0.8	2.5		5.	1.80				4.5		.05	192.8
Leamington	50								7.83				53.75	28.64	20.16			110.38
Cheltenham Saline	50								15.	4.5	11.		50.					80.5
Buxton	82	.2		.58		1.3				.07			.3		.07			13.9
Bath						.58			.9	9.5				1.2	1.6	.2	.019	14.
Tunbridge	50						.03			.18			.31	.05	.03		.28	.88

TABLE of Chemical Equivalents, or the Atomic Proportions of different Bodies. (THOMSON'S FIRST PR.)

N. B.—In the following Table, the atomic weights are given both according to the oxigen and hydrogen scale. The salts are supposed to be in their crystallized state, so that the number representing those having water of composition, is made up of those denoting the anhydrous salt in union with its due proportion of atoms of water.

A	ATOMIC WEIGHTS. Oxy. = 1	Hyd. = 1
Acetate of alumina	9.625	77
ammonia	16.25	130
barytes	19.375	135
cadmium	16.5	132
copper	12.375	99
iron	14.125	113
lead	23.625	159
lime	16.5	132
magnesia	14.375	115
manganese	15.25	122
mercury	36.75	294
nickel	16.125	129
potash	14.5	116
silver	21	168
soda	17	136
strontium	13.875	111
zinc	19.375	155
Acetic acid	6.25	50
Ditto, in crystals	7.375	59
Alcohol	2.875	23
Alum	60.875	487
Alumina	2.25	18
Aluminum	1.25	10
Ammonia	2.125	17
Ammonio-carbonate of uranium	49.875	399
Ammonio-muriate of copper	36.125	289
Ammonio-permuriate of iron	18.6875	149
Ammonio-muriate of platinum	27.75	222
Ammonio-oxalate of copper	19.625	156
Ammonio-oxalate of copper	12.75	102
Ammonio-phosphate of magnesia	16.125	129
Ammonio-phosphate of soda	31.125	249
Ammonio-sulphate of alumina	59.25	456
Ammonio-sulphate of copper	23.875	191
Ammonio-sulphate of magnesia	22.5	180
Ammonio-sulphate of manganese	24.5	196
Ammonio-sulphate of nickel	24.25	194
Ammonio-sulphate of potash	22.625	181
Ammonio-sulphate of soda	22.875	183
Ammonio-sulphate of zinc	25.25	202
Antimonic acid	7.5	60
Antimony	5.5	44
Arseniate of alumina	16.75	122
ammonia	9.875	79
bismuth	20.	160
cadmium	16.875	135
cobalt	16.5	182
lead	21.75	174
lime	11.25	90
magnesia	19.25	154
manganese	23.5	188
mercury	33.75	270
nickel	18.75	150
Subsesquarseniate of silver	29.875	237
Arseniate of strontian	23.25	186
zinc	22	176
Arsenic	4.75	38
Arsenic acid	7.75	54
Arsenietted hydrogen	4.875	39
Arsenious acid	6.75	46
Azote	1.75	14
B		
Barium	8.75	70
Barytes	9.75	78
Bichloride of mercury	34	272
platinum	21	168
selenium	14	12

	ATOMIC WEIGHTS.	
	Oxy. = 1	Hyd. = 1
Bichloride of tin	16.25	130
Benzoate of ammonia	18.25	146
lead	30.125	241
potash	24.375	145
Benzoic acid	15	120
Bicarbonate of ammonia	8.75	70
potash	12.625	101
soda	10.625	85
Bichromate of ammonia	17.375	139
potash	19	152
Bifluoborate of ammonia	10.625	85
Bifluosilicate of ammonia	8.625	69
Bihydrate of alumina	4.5	36
Bihydroguret of phosphorus	1.75	14
Bimuriate of tin	21.875	213
Binarseniate of ammonia	19.875	159
nickel	31	248
potash	22.625	181
soda	43.125	166
Binoxalate of ammonia	20.125	71
barytes	22.125	177
magnesia	19.375	155
potash	17.25	138
soda	16.375	131
strontian	15.5	124
Biphosphate of ammonia	7.875	73
strontian	15.75	146
Bisilicate of lime	7.5	60
magnesia	8.5	68
Bisulphate of cobalt	17.625	141
glucina	18.875	151
potash	18.25	146
Bismuth	9	72
Bisulphuret of carbon	4.75	38
copper	8	64
iron	7.5	60
lead	17	136
mercury	29	232
platinum	16	128
tin	11.25	90
Bitartrate of magnesia	20.125	161
potash	24.75	198
Bitungstate of ammonia	41.875	335
lead	51.5	412
Boracic acid	3	24
Boron	1	8
Brucia	51.5	412

C

Cadmium	7	56
Calcium	2.5	20
Carbon	0.75	6
Carbonate of ammonia	3.875	31
barytes	12.5	100
Carbonate of cadmium	10.75	86
cobalt	8.125	65
iron	7.25	58
lead	16.75	50
lime	6.25	50
magnesia	5.25	42
manganese	9.5	76
nickel	10.375	83
potash	11	135
silver	17 5	140
soda	18	83
strontian	9.25	74
uranium	31.875	255
yttria	9.125	73
zinc	9.125	73
Carbonic acid	2.75	22
oxid	1.75	14
Carburetted hydrogen	1	8
Cerium	6.25	50
Chloric acid	9.5	76
Chloride of antimony	10	80
barium	13.25	106
bismuth	13.5	108
cadmium	11.5	92
cerium	10.75	86
chromium	8	84
cobalt	7.75	62
copper	8.5	68
glucinum	6.75	54
gold	29.5	236
iron	8	64
lead	17.5	140
lime	7	56
lithium	5.75	46
magnesium	6	48
manganese	8	64
mercury	29.5	236
nickel	7.25	58
palladium	11.5	92
platinum	16.5	132
potassium	9.5	76
rhodium	10	80
silver	18.25	146
sodium	7.5	60
strontium	10	80
sulphur	6.5	52
tin	11.75	94
uranium	30.5	244
yttrium	8.75	70
zinc	8.75	70
zirconium	9.5	76
Chlorocarbonic acid	6.25	50
Chlorocyanic acid	7.75	62
Chlorine	4.5	36
Chloriodic acid	24.5	196
Chromate of ammonia	8.625	69
barytes	16.25	130

	ATOMIC WEIGHTS.	
	Oxy. = 1	Hyd. = 1
Chromate of bismuth	18.75	150
cadmium	20.125	161
chromium	11	88
cobalt	13	104
copper	13.75	110
lead	20.5	164
lime	10	80
magnesia	11.25	90
mercury	32.5	260
nickel	15.25	122
potash	12.5	100
silver	21.25	170
soda	24	192
strontian	13	104
zinc	11.75	94
Chromic acid	6.5	52
Chromium	3.5	28
Citric acid	7.25	58
Ditto, in crystals	9.5	76
Cobalt	3.25	26
Columbate of soda	34.25	274
Columbic acid	19	152
Columbium	18	144
Copper	4	32
Cyanogen	3.25	26
D		
Decahydrate of chlorine	15.75	126
Deutosulphuret of potassium	9	72
Deutoxid of azote	3.75	30
chromium	5.5	44
hydrogen	2.125	17
lead	14.5	116
manganese	5	40
Diacetate of copper *	23	184
lead	34.25	364
Dicarbonate of copper	13.875	111
Dichloride of antimony	15.5	124
copper	12.5	100
Dihydrate of silica	5.125	40
Dinitrite of lead	36	288
alumina	22.5	180
bismuth	20	232
Diprotarseniate of iron	20.125	161
Diphosphate of lead	31.5	152
Disulphuret of copper	10	80
lead	28	224
E		
Ether, sulphuric	4.625	37

	ATOMIC WEIGHTS.	
	Oxy. = 1	Hyd. = 1
F		
Fluoborate of ammonia	6.375	51
Fluoboric acid	4.25	34
Fluoric acid ?	2.375	19
Fluorine ?	2.25	18
Fluosilicic acid	3.25	26
Formate of copper	14.125	113
lead	19.75	158
Formic acid	4.625	37
Fuming sulphuric acid	11.125	89
G		
Gallic acid	7.75 ?	62 ?
Glucina	3.25	26
Glucinum	2.25	18
Gold	25	200
Gum	11.25	90
H		
Hydrate of alumina	3.375	27
silica	3.125	25
zirconia	7.125	56
Hydriodic acid	15.625	125
Hydrocyanic acid	3.375	27
Hydrogen	0.125	1
Hyponitrite of lead	19.875	159
Hyponitrous acid	4.75	38
Hyposulphuric acid	9	32
Hyposulphurous acid	3	24
I		
Iodic acid	20.5	164
Iodid of barium	24.25	194
bismuth	24.5	196
cadmium	22.5	180
calcium	18	144
copper	19.5	156
iron	19	152
lead	28.5	228
phosphorus	17	136
potassium	20.5	164
silver	29.25	234
sodium	18.5	148
strontium	21	168
sulphur	17.5	140
zinc	19.75	158
Iodine	15.5	124
Iridium	3.75	30
Iron	3.5	28

* The syllable *di*, is added to shew that the salt contains two atoms of base, (δις, *twice*.)

	ATOMIC WEIGHTS.	
K	Oxy. = 1	Hyd. = 1
Kermes mineral	7.625	61
L		
Lead	13	104
Lime	3.5	28
Lithia	2.25	18
Lithium	1.25	10
M		
Magnesia	2.5	20
Magnesium	1.5	12
Manganese	3.5	28
Manganesic acid	7.5 ?	60
Manganesous acid	6.5 ?	52
Margaric acid	33	264
Mercury	25	200
Molybdate of ammonia	21.25	170
lead	23	184
Molybdenum	6	48
Molybdic acid	9	72
Molybdous acid	8	64
Morphia	40.25	322
Muriate of alumina	10.25	82
ammonia	6.75	54
barytes	15.5	124
cadmium	13.75	110
chromium	19.25	154
cobalt	13.375	107
copper	11.875	95
glucina	7.875	63
iron	12.5	100
lime	14.875	119
magnesia	12.75	102
manganese	13.625	109
nickel	14.5	116
strontian	20.125	161
zinc	9 875	79
zirconia	16.25	130
Muriatic acid	4.625	37
N		
Naphtha	5.25	42
Naphthaline	1.25	1
Nickel	3.25	26
Nitrate of ammonia	10	80
barytes	16.5	132
bismuth	20.125	161
Nitrate of cadmium	19.25	154
cobalt	17.75	142
copper	19.625	157
iron	19.125	153
lead	20.75	166
lime	17	136
magnesia	16	128
manganese	19.125	153
mercury	35	280
nickel	16 625	133
potash	12.75	102
silver	21.5	172
soda	10 75	86
strontian	13.25	142
zinc	18.75	140
Nitrous acid	5.75	46
Nitric acid	6.75	54
O		
Oil of vitriol	6	49
Olefiant gas	1.75 *	14
Oleic acid	36	288
Orpiment	7.75	62
Oxalate of alumina	10.125	81
ammonia	8.875	71
barytes	17.625	141
bismuth	14.5	116
cadmium	15.875	127
cobalt	11	88
copper	10.625	85
iron	11.25	90
lead	18.5	148
lime	10.25	82
magnesia	9.25	74
manganese	12.375	99
mercury	31.625	253
nickel	13.25	106
potash	11.625	93
silver	19.25	154
soda	8 5	68
strontian	13.25	106
zinc	12	96
Oxalic acid	4.5	36
crystals	9	72
Oxid of bismuth	10	80
cadmium	8	84
copper	5	40
palladium	8	84
silver	14.75	118
tellurium	5	40
tungsten	17.75	142
zinc	5.25	42

* Though Dr T. assigns 1.75 as the atomic weight of olefiant gas, I am inclined to think it should be .875, as it seems to be a compound of an atom of each of its ingredients, (.75 + .125 = .875,) or, according to the hydrogen scale, 7, (6 + 1 = 7.)

	ATOMIC WEIGHTS.	
	Oxy. = 1	Hyd. = 1
Oxigen - - -	1	8
P		
Palladium - - -	7	56
Perchloric acid - -	11.5	92
Perchlorid of iron -	12.5 ?	100
phosphorus	10.5	84
tin -	16.25	130
Pernitrate of mercury	33.75	270
Periodid of mercury -	40.5	448
phosphorus	32.5	260
Peroxid of antimony	7.5	60
barium -	10.75 ?	86
cerium -	7.75	58
cobalt -	4.75	38
gold -	28	224
iridium -	5.75 ?	
iron -	5	40
lead -	15	120
mercury -	27	216
nickel -	4.75	38
platinum -	14	112
potassium -	8	64
rhodium -	7.5	60
sodium -	4.5	36
tin - -	9.25	74
uranium -	28	224
Persulphate of mercury	33.25	256
Persulphuret of copper	8	64
gold	31	248
iron	7.5	60
lead	17	136
mercury	29	232
platinum	16	128
potassium	15	120
tin	11.25	90
Phosphate of alumina -	9.125	73
ammonia	7.875	63
barytes -	13.25	106
bismuth	16.875	135
cadmium	12.625	101
cobalt	10	80
copper -	9.625	77
iron -	11.375	91
lead -	17.5	140
lime -	7	56
magnesia	13.875	111
mercury	29.5	236
nickel -	11.125	89
potash -	10.625	85
silver -	18.25	146
soda -	21	168
strontian	11.125	89
zinc -	11	88
Phosphoric acid - -	3.5	28
Phosphorous acid -	2.5	20
Phosphorus - -	1.5	12
Phosphuret of carbon -	2.25	18
sulphur	3.5	28
Phosphuretted hydrogen	1.625	13
Picrotoxia - - -	45	360
Platinum - - -	12	96
Potash - - -	6	48
sulphate of alumina	60.875	451
tartrate of soda	35.5	284
Potassium - -	5	40
Protiodid of mercury -	40.5	324
Protochlorid of phosphorus - - -	6	48
tin -	11.75	94
Protohydrate of sulphuric acid - - -	6.125	49
Protosulphuret of antimony - - -	7.5	6
arsenic	6.75	5
iron -	5.5	44
mercury	27	216
platinum	14	112
potassium	7	56
tin -	9.25	74
Protoxid of antimony -	6.5	52
azote -	2.75	22
barium -	9.75	78
cerium -	7.25	62
chlorine -	55	44
chromium	4.5	36
cobalt -	4.25	34
gold -	26	208
iron -	4.5	36
lead -	14	112
manganese	4.5	36
mercury -	26	208
nickel -	4.25	34
platinum	13	104
potassium -	6	48
rhodium -	6.5	52
sodium -	4	32
tin - -	8.25	66
uranium -	27	216
Q		
Quadrochlorid of azote	19.75	158
Quadrosulphuret of potassium - - -	13	104
Quadroxalate of potash	31.875	255
Quadroxid of chlorine -	8.5	68
Quintosulphuret of potassium - - -	15	120

R	ATOMIC WEIGHTS. Oxy. = 7	Hyd. = 7
Realgar	6.75	54
Red oxid of lead	14.5	116
Rhodium	5.5	44
S		
Saclactate of ammonia	16.25	130
soda	22.625	181
Saclactic acid	13	104
Selenic acid	7	56
Selenium	5	40
Seleniet of arsenic	9.75	78
Selenietted hydrogen	5.125	41
Sesquicarbonate of ammonia	7.375	59
mercury	30.125	241
potash	16.875	135
soda	10.375	83
Sesquichloride of iron	10.25	82
Sesquisilicate of copper	9.125	73
soda	7	56
Sesquisulphuret of arsenic	7.75	62
iron	6.5	52
tin	10.25	82
Sesquisulphate of uranium	40	320
Sesquiuraniate of barytes	51.75	414
Silica	2	16
Silicate of alumina	4.25	34
iron	6.5	52
zinc	7.25	58
Silicon	1	8
Silver	13.75	110
Soda	4	32
Sodium	3	24
Starch	17.75	142
Strontian	6.5	52
Strontium	5.5	44
Strychnia	47.5 ?	380 ?
Sub-bichloride of sulphur	8.5	68
Suboxid of copper	9	72
manganese	4	32
Subphosphuretted hydrogen	1.25	10
Subsesquacetate of copper	17.125	137
Subsesquarseniate of lead	28.75	230
Succinate of ammonia	10.625	85
lead	20.25	162
soda	17	136
Succinic acid	6.25	50
Sugar	10.125	81
Sulphate of alumina	15.125	121
ammonia	8.25	66
barytes	14.75	118
bismuth	15	120
cadmium	17.5	140
Sulphate of cerium	15.625	125
cobalt	17.125	137
copper	15.625	125
iron	17.375	139
lead	19	152
lime	10.75	86
lithia	8.375	67
magnesia	15.375	123
manganese	15.125	121
mercury	33.25	266
nickel	17.125	137
platinum	19	152
potash	11	88
silver	19.75	158
soda	20.25	162
strontian	11.5	92
yttria	10.25	82
zinc	18.125	145
Sulphochyazic acid	7.375 ?	61 ?
Sulphur	2	16
Sulphuret of antimony	7.5	66
arsenic	6.75	54
barium	10.75	86
bismuth	11	88
cadmium	9	72
calcium	4.5	36
cerium	8.25 ?	66 ?
chromium	5.5	44
cobalt	5.25	42
columbium	20	160
copper	6	48
iron	5.5	44
lead	15	120
lithium	3.25 ?	26 ?
magnesium	3.5	28
manganese	5.5	44
mercury	27	216
nickel	5.25	42
palladium	9	72
platinum	14	112
potassium	7	56
rhodium	7.5	60
silver	15.75	126
sodium	5	40
strontium	7.5	60
tin	9.25	74
titanium	6	48
uranium	28	224
zinc	6.25	50
Sulphuretted hydrogen	2.125	17
Sulphuric acid	5	40
ether	4.625	37
Sulphurous acid	4	32
T		
Tannin	8.75 ?	70 ?

	ATOMIC WEIGHTS.	
	Oxy. = 1	Hyd. = 1
Tartar emetic	44.25	354 ?
Tartaric acid	8.25	66
crystals	9.375	75
Tartrate of alumina	11.625	93
ammonia	10.375	83
barytes	18	144
bismuth	23.875	191
cadmium	18.5	148
cobalt	14.75	116
copper	16.625	133
iron	15	120
lead	22.25	178
lime	16.25	130
magnesia	13	104
manganese	15	120
mercury	34.25	284
nickel	12.5	100
potash	16.5	132
silver	23	184
soda	14.5	116
strontian	18.125	145
zinc	13.5	108
Telluretted hydrogen	4.125	33
Tellurium	4	32
Tin	7.25	58
Titanic acid	6	48
Titanium	4	32
Triscarbonate of bismuth	35	280
Trisnitrate of alumina	20.25	162
Trisilicate of iron	10.5	84
Tritantimoniate of potash	28.5	228
Tritiodid of azote	37.25 ?	298 ?
Tritoxid of chlorine	7.5	
Tungstate of lead	32.75	262
soda	29.5	236
Tungsten	15.75	126
Tungstic acid	18.75	150
U		
Uranium	26	208
Urate of soda	14.125	113
Uric acid	9	72
crystals	11.25	90
W		
Water	1.125	9
Y		
Yttria	5.25	42
Yttrium	4.25	34
Z		
Zinc	4.25	34
Zirconia	6	48
Zirconium	5	40

*

Instead of having substances arranged as in the preceding table, if they be placed in the order of the weights of their atoms, and the numbers denoting these be put on a slide, divided by them in the same way as in Gunter's scale, a great deal of useful information is derived from it, and much labour is saved. This constitutes the *Scale of Chemical Equivalents*, the ingenious contrivance of Dr Wollaston. It consists of a slide, with the numbers arranged as already mentioned, and the fixed part, on which are placed the names of bodies much used in analysis, so

* In the above table, oxigen is taken as 1. If it is wished to call it 10, all that is necessary in adapting the numbers of other bodies to it, is to move the decimal point in the oxigen column a figure to the right; or, where there is only one figure and no decimal, to add 0. Thus zinc, instead of being 4.25, will be 42.5; and zirconia, instead of 6, will be 60.

situated, that when the standard (oxigen) is at 10, they are immediately opposite the numbers denoting their atomic weight. The uses of this scale are :—

1*st*, *We at once find the combining proportions of simple bodies.*—Thus, oxigen being at 10, sodium is at 30, so that 10 of the former and 30 of the latter unite, and the name of the resulting compound, soda, is of course at 40. The number denoting sulphur is 20, so that oxigen and it unite in the proportions of 10 and 20, to form hypo-sulphurous acid. But sulphur combines with 2 and with 3 atoms of oxigen, so that 20 combine with 20 and with 30, to form sulphurous and sulphuric acid. When compounds combine with compounds, it is according to their atomic proportions ; thus 40 of soda unite with 50 of sulphuric acid, and sulphate of soda is opposite 90 *.

2*d*, *We find the proportions of the ingredients of compounds.*—Phosphate of potassa, for instance, is opposite 95, and by looking for phosphoric acid, we find it at 35, and potassa at 60, so that 95 of the salt contain 35 of acid and 60 of alkali. Opposite potassium is 50, so that 60 of potassa consist of 50 of base and 10 of oxigen ; and opposite phosphorus is 15, so that 35 of phosphoric acid contain 15 of base, the remainder, 20, is oxigen ; but oxigen in the scale is 10, hence the acid must have 1 atom of phosphorus, and 2 of oxigen.

3*d*, *We find the quantity of one body necessary for the decomposition of another.*—Thus, carbonate of lime is opposite 63.5, tartaric acid opposite 82.5. Now, since this acid

* As the scale would be inconveniently long were all substances placed immediately opposite their atomic numbers, the names of a few are put at their number, multiplied by 10. Thus, carbon should be at 7.5, and hydrogen at 1.25, numbers not on the slide, instead of which they are opposite 75 and 12.5. Hence, in finding the composition of any body containing these, the number given by the scale must be divided by 10. Thus, water is opposite 11.25 ; in wishing to find its composition, we observe oxigen at 10, and hydrogen at 12.5, but the last must be divided by 10 ; *i. e.* the decimal point must be brought in a figure to the left, making it 1.25, so that water is composed of oxigen 10 + hydrogen 1.25 = 11.25. The substances thus situated, have 10 placed before them.

will unite with lime, it must do so in proportion according to the number applied to it, which is 36; but 63.5 of carbonate contain 36 of lime, so that 82.5 of tartaric acid will decompose 63.5 of carbonate.

4th, We find the quantity of the newly formed products.—In the instance given, 82.5 of tartaric acid being added to 63.5 of carbonate of lime, the products are 118.5 of tartrate of lime, and 27.5 of carbonic acid.

These remarks apply also to the decomposition of compounds by compounds. Thus, 90 of sulphate of soda, require 165 of nitrate of baryta, and the products are 147.5 of sulphate of baryta, and 107.5 of nitrate of soda.

5th, Since the part with the numbers is moveable, instead of always keeping the same opposite the different bodies, we may place any numbers to them, and thus *we are enabled to find the composition of any quantity of a compound, or the quantity of a body necessary for the decomposition of any quantity of another.*—If for instance the slide be pushed up till 20 is opposite oxigen, (twice its original number,) it will be observed that the numbers opposite all other bodies are also doubled. If 30 be put opposite it, other substances are trebled. If the slide be brought down till 10 is at sulphur, (half its original number,) the numbers of all others are reduced to a half, and so on; by whatever number we multiply or divide any one substance, by moving the slide upwards or downwards, we multiply or divide all others exactly in the same ratio. Suppose now, that we wish to find the quantity of sodium that 16 of oxigen will unite with. Having moved the slide up till 16 is at oxigen, sodium will be found opposite 48, so that 16 of the former unite with 48 of the latter, and produce 64 of soda, opposite which soda will be found. Again, suppose we wish to find the proportions of the ingredients of 64 of phosphate of potass. Having brought the slide down till 64 is opposite it, we find phosphoric acid at 23.5, and potass at 40.5, so that these are the proportions of the ingredients. In the same way, by placing the number denoting the weight of any compound opposite its name on the scale, the proportion of any simple or compound necessary for its

decomposition, and the quantity of the newly formed compounds, are ascertained.

6th, We can find the equivalent of the different salts; that is, if we have a certain quantity of sulphate of soda, we ascertain how much sulphate of lime, or indeed of any other sulphate, the acid in it would form; or we find how much carbonate of soda, or of any other soda salt the alkali in the sulphate would yield. If, for instance, a mineral water has yielded by evaporation 72 of sulphate of lime, and 96 muriate of soda, but we suppose the lime to exist in the water as muriate, having put 72 opposite sulphate of lime, we find its composition to be 41.8 of acid and 30.2 of earth; the quantity of muriatic acid with which the lime should combine, is denoted by the number opposite it, which is 29.3, so that 72 of sulphate of lime are equivalent to 59.5 of muriate, (30.2 of lime + 29.3 of muriatic acid = 59.5); the quantity of soda with which the sulphuric acid should be in union, is also pointed out by the number at it, which is 33.45, so that 72 of sulphate of lime are equivalent to 75.25 of sulphate of soda, (41.8 + 33.45 = 75.25.)

Dr Wollaston has chosen oxigen as his standard, calling it 10, but with the same scale the hydrogen standard may be taken. All that is necessary, is to draw the slide down till 10 is at hydrogen, and then the other bodies are opposite their atomic numbers. (See the original paper of Wollaston, Ph. Tr. 1814.)

GLOSSARY.

ALKALI, (from the Arabic *al*, *kali*, the salt,) a name originally given to the salt (carbonate of potass,) procured from certain vegetables, but now applied to potassa, soda, and ammonia; and hence also

ALKALIFIABLE, which, in its most extended signification, means a substance generating a compound, that, with others, forms salts.

ANALYSES, (αναλυω, to separate,) decomposition or separation of the ingredients of a compound.

ANHYDROUS, (α, priv. ὑδορ, water,) a term attached to the names of bodies, to shew that they do not contain water.

BAROMETER, (βαρυς, heavy, and μετρον, a measure,) an instrument for measuring the pressure of the air.

CALORIC, (from the Latin *calor*), a term employed to denote the agent by which heat is produced.

CALORIMETER, (calor, and μετρον, a measure,) an instrument invented by Lavoisier and Laplace, for ascertaining the heat given out by bodies.

CALX, a term used to denote the oxids of metals, from their being more spongy than the metals themselves.

CHLORINE, (χλωρος, green,) so called from its greenish colour.

CREOPHYRUS, (κρυος, cold, and φερω, to bear,) an instrument contrived by Wollaston, for shewing the generation of cold by evaporation.

CYANOGEN, (κυανος, cæruleus, and γενναω, to generate,) so called from its generating compounds of a blue colour.

DECREPITATION, (*crepito*, to crackle,) salts splitting with a crackling noise, when heated, from the conversion of their water into vapour.

DELIQUESCENCE, (*deliquesco*, to become moist,) salts absorbing moisture when exposed to the air.

DEFLAGRATION, a term applied originally to denote the action of bodies containing oxigen on inflammables, by which they burn as in air or oxigen.

EFFERVESCENCE, (*effervesco*, to boil over,) the disengagement of a gas from a fluid, or from a solid by the action of a fluid.

EFFLORESCENCE, (*effloresco*, to blow like a flower,) salts losing their water of crystallization, and becoming a dry powder.

ELECTRICITY, (ηλεκτρον, amber,) amber being the substance first found to excite electricity by friction.

EUDIOMETRY, (ευ, *bene*, and μετρον,) a term used originally to denote a process for ascertaining the purity of air, the atmosphere being, at one time, supposed to contain, in different places, different proportions of oxigen, or the pure part of the air, as it was called; but now used to signify the analysis of gases in general.

HYDRATE and HYDROUS, (ὑδωρ, water,) terms attached to other words to shew the presence of water.

HYDRO, a term attached to the names of bodies, to shew that they contain hydrogen.

HYDROGEN, (ὑδωρ, water, γενναω, to generate), because, by its union with oxigen, it forms water.

HYGROMETERS, (ὑγρος, humidus,) instruments used for ascertaining the state of the atmosphere with respect to moisture.

HYPER, (ὑπερ, above,) a term attached to the names of other bodies, to shew that one of the ingredients is in larger quantity than in that to the name of which it is fixed; *hyper-chloric acid* has more oxigen than *chloric* has.

HYPO, (ὑπο, under,) a term attached to the names of bodies, to shew that one of the ingredients is in less quantity than in that the name of which it is attached to; thus, *hypo-nitrous* acid has less oxigen than *nitrous*.

IODINE, (ιωδης, violaceous,) so called from the colour of its vapour.

MENSTRUUM, (*mensis*, a month,) a fluid used for dissolving a solid, so called, because in many cases a considerable time was required to complete the solution.

MORDANT, (*mordeo*, to bite,) a substance used to fix colour on cloth, so called from the idea of its *biting it in*.

NASCENT STATE, (*nasco*, to be born,) a term used to denote when a body is just set free from another with which it was in union, being as it were then brought into existence.

NEUTRALISATION, (*neuter*, neither,) when one body has combined with another, and the properties of both are destroyed.

NITROGEN, (*nitre*, and γενναω, to generate,) because by its union with oxigen, it forms nitric acid, a component part of nitre.

OXIGEN, (οξυς, acid, γενναω, to generate,) from its being supposed to be the generator of water.

OXID, a substance containing oxigen, not having acid properties.

PHLOGISTON, (φλοξ, flame,) the supposed principle of heat and light of Stahl.

PHOSPHORESCENCE, (φως, light, and φερω, the emission of light,) hence also phosphorus.

PNEUMATIC, (πνευμα, air,) of or belonging to air; *pneumatic trough*, *pneumatic chemistry*.

PRECIPITATION, (*precipito*, to throw down,) the formation of a solid by the action of fluids, the solid falling to the bottom.

PYRO, (πυρ, fire,) a term attached to the names of other bodies, to shew that they have been produced by the action of fire; *pyro-ligneous* acid, is acid got from wood by exposure to a strong heat.

PYROMETER, (πυρ, fire,) an instrument for ascertaining high temperatures.

SATURATION, when a fluid has dissolved as much as it can of a solid, it is said to be saturated.

SOLUTION, (*solvo*, to loosen,) the action between a solid and fluid, the former becoming fluid.

SYNTHESIS, (συντεθημι, to put together,) the union of bodies by chemical attraction.

THERMOMETER, (θερμη, heat, and μετρον, a measure,) an instrument for ascertaining temperature.

——————— DIFFERENTIAL, of Leslie, for pointing out the difference between the temperature of its balls.

——————— CENTIGRADE, so called, because the space from the freezing to the boiling points, is divided into 100 degrees.

——————— REGISTER, for indicating the highest or lowest temperature during any time.

THERMOSCOPE, (θερμη, heat, and σκοπος, scopus,) an instrument contrived by Leslie, for measuring the effect of radiant heat.

VITRIOLS, (*vitreum*, glass,) bodies having a vitreous appearance.

VITRIOL, oil of, sulphuric acid, a fluid of an oily consistence got from *green vitriol*, or sulphate of iron.

WATERY FUSION, salts, when slightly heated, becoming fluid, from their being dissolved by their water of crystallization, to distinguish it from fusion by heat alone.

XANTHOGEN, (ξανθος, and γενναω, to generate,) so called from the yellow colour of some of its compounds.

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